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P-3 ORION FUEL-SAVING MODIFICATION WIND TUNNEL STUDY

by

Andrew G. Lee

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AVIATION AND SURFACE EFFECTS DEPARTMENT

DTNSRDC/ASED-80/14

June 1980

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In conjunction with the Naval Air Development Center and the Lockheed California Company, the Aviation and Surface Effects Department of the David W. Taylor Naval Ship Research and Development Center investigated the potential drag reduction of the P-3 Orion aircraft through various modifications to the engine nacelles. A 1/16-scale model was used in the 7- by 10-foot transonic wind tunnel experiments conducted over an angle of attack

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NOTATION

ALPHA, α	Angle of attack in degrees (angle between aircraft reference line and projection of the relative wind vector on the plane of symmetry of the aircraft)
b	Span of wing in feet
CDS	Coefficient of drag in stability axis system (= D/qS)
CLS	Coefficient of lift in stability axis system (= L/qS)
CMS	Coefficient of pitching moment in stability axis system (= M/qSc)
CONFIGURATION CODE	Model configuration description code
CONFIGURATION #	Model configuration number
$\bar{c}$	Mean aerodynamic chord in inches
D	Drag in pounds
L	Lift in pounds
L/D	Lift to drag ratio
MACH NO.	Mach number
P_o	Total air pressure in pounds per square foot
P_s	Static air pressure in pounds per square foot
Q, q	Dynamic pressure in pounds per square foot ($\rho V^2/2$)
R_N	Reynolds number
S	Area of wing in square feet
T_o	Air temperature
ρ	Mass density of air in slugs per cubic foot

ABSTRACT

In conjunction with the Naval Air Development Center and the Lockheed California Company, the Aviation and Surface Effects Department of the David W. Taylor Naval Ship Research and Development Center investigated the potential drag reduction of the P-3 Orion aircraft through various modifications to the engine nacelles. A 1/16-scale model was used in the 7- by 10-foot transonic wind tunnel experiments conducted over an angle of attack range of -4 to 7 deg. Force data were taken on 14 different model configurations with all modifications in the engine nacelle areas of the P-3 Orion. The experiments were conducted as part of the P-3 Fuel-Saving Modifications Program.

ADMINISTRATIVE INFORMATION

The testing reported herein was funded by the Naval Air Development Center (NADC) under Work Request 00525. The work was conducted by the Aircraft Division of the Aviation and Surface Effects Department at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) under DTNSRDC Work Units 1660-800 and 1660-801. This project is part of the Navy Energy Research and Development Program.

INTRODUCTION

A static force test of a 1/16-scale P-3 Orion aircraft was conducted in the 7- by 10-ft transonic wind tunnel of the David W. Taylor Naval Ship Research and Development Center. The experiments were performed from 26 November to 07 December 1979 for the Naval Air Development Center under the P-3 Fuel-Saving Modifications Program.

MODEL DESCRIPTION

The P-3 Orion model used for the experiment was a 1/16-scale version without propellers. The model and all model hardware were supplied by the Lockheed California Company. The model was constructed of a combination of wood, metal, and plaster.

Fourteen different model configurations were investigated during the test. These configurations consisted of the baseline model and modifications to the baseline configuration by adding various fillets around the engine nacelles on the upper and lower wing surfaces. Some of the fillets

were designed before the experiment; other fillets were designed during the experiment after preliminary analysis of the initial results. A brief description of each of the fillets tested, with the identifying configuration coding is presented in Table 1. (In general, a "U" in the configuration code indicates fillets have been added to the nacelles at the upper wing surface, and an "L" indicates a fillet has been added to the nacelle at the lower wing surface.)

TABLE 1 - CONFIGURATION DESCRIPTION

Code	General Description
Baseline	Basic unmodified P-3c aircraft; corresponds to Configuration 1.
Modified Baseline	Basic unmodified P-3c aircraft with twice the typical amount of transition grit applied to the model; corresponds to Configuration 11.
U_1	The basic aircraft modified with upper-wing nacelle fillets on all four engines. The fillets enlarge the cross-sectional area of the aft portion of each nacelle to the corresponding area at the wing maximum thickness location. An additional small fairing on the bottom of the nacelles aft of the wing has been added; corresponds to Configuration 2.
U_2	Nacelle fillets are similar in planform to "U_1." The cross-sectional area of the fillets is only 50 percent of the area of "U_1"; used in Configurations 3 and 4.
U_3	Nacelle fillets are on all four engines. The same as "U_2" except the small fairing on the bottom of the nacelles has been removed; corresponds to Configuration 5.
U_4	Nacelle fillets are on all four engines. Similar to "U_3" but increased in size making the nacelle a more cylindrical shape on the upper wing surface; corresponds to Configuration 6.
U_5	Nacelle fillets are the same as "U_4" with a V-shaped fairing added to the end of the flap and adjoining the tail cone section of the nacelle. All four nacelles have been modified; corresponds to Configuration 7.

TABLE 1 (Continued)

Code	General Description
U_6	Nacelle fillets on all four engines are the same as "U_5" except the rounded lower surface of the nacelle tail cone has been flattened level with the bottom of the flap; used in Configurations 9 and 10.
L_1	Nacelle fairings on the lower wing surface extending from the existing nacelle back over the flap to the rear flap edge. Added to the inner two engines only; used in Configurations 4, 5, 6, 7, and 10.
L_2	Nacelle fairings added to the lower wing surface behind the inner two engines extending from the existing nacelle about 75 percent of the distance to the rear flap edge; corresponds to Configuration 13.
L_3	Nacelle fairings added behind the inner two engines similar to "L_2" except extending only about 50 percent of the distance to the flap edge; corresponds to Configuration 14.
F_1	A small fillet applied to the junctions of all four engine nacelles and the upper wing surface; corresponds to Configuration 12.

WIND TUNNEL CONDITIONS AND PROCEDURES

The majority of the wind tunnel program was conducted at Mach 0.25 with atmospheric conditions. Ten runs were conducted at partially evacuated pressures down to 12 in. of mercury at Mach numbers 0.4 to 0.7. The model was not yawed nor rolled during the experiment; only alpha sweeps were conducted. The alpha range was from -4.0 deg to +7.0 deg in 0.5-deg increments. The run log for the test is presented in Table 2.

TABLE 2 - P-3 FUEL-SAVING MODIFICATION STUDY RUN LOG

Run*	Configuration Code		α** Series	Mach	Date
2	1	Baseline	1	0.25	11-26
4	1	Baseline	3	0.70	11-27
5	1	Baseline	3	0.60	11-27
6	1	Baseline	2	0.50	11-27
7	1	Baseline	1	0.40	11-27
8	1	Baseline	1	0.25	11-27
9	1	Baseline	2.0 deg	0.25	11-27
11	2	$+U_1$	1	0.25	11-27
12	2	$+U_1$	2.0 deg	0.25	11-27
14	3	$+U_2$	1	0.25	11-28
15	3	$+U_2$	2.0 deg	0.25	11-28
18	4	$+U_2L_1$	1	0.25	11-28
19	3	$+U_2$	4	0.25	11-28
23	5	$+U_3L_1$	1	0.25	11-29
25	6	$+U_4L_1$	1	0.25	11-29
27	7	$+U_5L_1$	1	0.25	11-29
29	8	$+L_1$	1	0.25	11-29
30	1	Baseline	1	0.25	11-29
32	9	$+U_6$	3	0.60	11-30
33	9	$+U_6$	2	0.50	11-30
34	9	$+U_6$	4	0.40	11-30
35	9	$+U_6$	1	0.25	11-30
38	10	$+U_6L_1$	1	0.25	11-30
39	10	$+U_6L_1$	3	0.60	11-30
40	10	$+U_6L_1$	2	0.50	11-30
41	10	$+U_6L_1$	4	0.40	11-30
43	1	Baseline	4	0.25	12-06
45	1	Baseline	4	0.25	12-06
47	11	Mod. Baseline	4	0.25	12-06

TABLE 2 (Continued)

Run*	Configuration Code		α** Series	Mach	Date
49	12	$+F_1$	4	0.25	12-06
51	13	$+L_2$	2	0.25	12-07
53	14	$+L_3$	2	0.25	12-07
55	1	Baseline	2	0.25	12-07

*Runs 1, 3, 10, 13, 16, 20, 22, 24, 26, 31, 37, 42, 44, 46, 48, 50, 52, and 54 were weight tare runs; runs 17, 21, and 36 were aborted runs.

**α Series Description

α_1 = -4.0, -3.0, -2.0, -1.5, -1.0, -0.5, 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 6.0, 4.0, 3.0, 2.0, 0.0

α_2 = -4.0, -3.0, -2.0, -1.5, -1.0, -0.5, 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 2.5, 0.0

α_3 = -4.0, -3.0, -2.0, -1.5, -1.0, -0.5, 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 2.0, 0.0

α_4 = -2.0, 0.0, 2.0, 3.0, 4.0, 6.0

Of the 55 total runs, 30 were data taking runs, 3 were oil flow runs, 19 were weight tare runs, and 3 were aborted runs. The weight tare runs were used in determining correction factors, which are applied to the raw data to remove the effects of the model weight.

The final plotted data are presented in the Appendix. The data are presented in four sets of 13 model configuration comparison plots. The four sets of plots are:

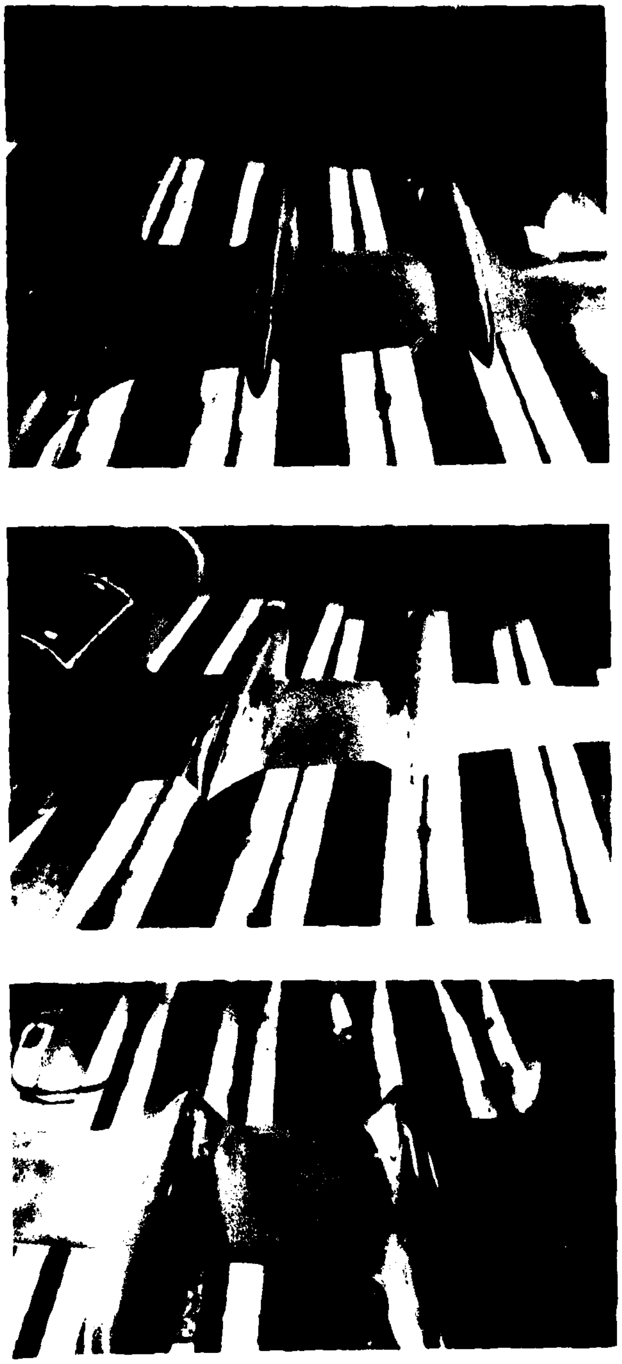
1. lift coefficient versus drag coefficient,
2. lift coefficient versus alpha,
3. lift coefficient versus lift to drag ratio, and
4. pitching moment coefficient versus lift coefficient.

The oil flow runs were conducted to give a visual display of the airflow over the wing and fuselage. This was done in two steps: first, a strip of special oil was applied near the front of the wing and fuselage;

then the wind speed was brought up, held for a short time, and returned to zero. This process leaves a wind blown covering of oil on the wing and fuselage and visually describes the airflow and vortices acting on the aircraft.

DATA SUMMARY

The experimental data are presented in the Appendix. Analysis of the data indicates that some fuel savings is possible through modifications to the engine nacelles. The combination configuration U_6L_1 produces less drag than does the baseline model. This particular configuration is described in Table 1 and is shown in Figures 1 and 2. Figure 1 shows the difference between configuration U_6 and the baseline configuration, and Figure 2 compares configuration L_1 and the baseline configuration.



Baseline Configuration

Configuration U_6

Configuration U_6

Figure 1 - Comparison of the Baseline Configuration and Configuration U_6

Baseline Configuration

Configuration L_1

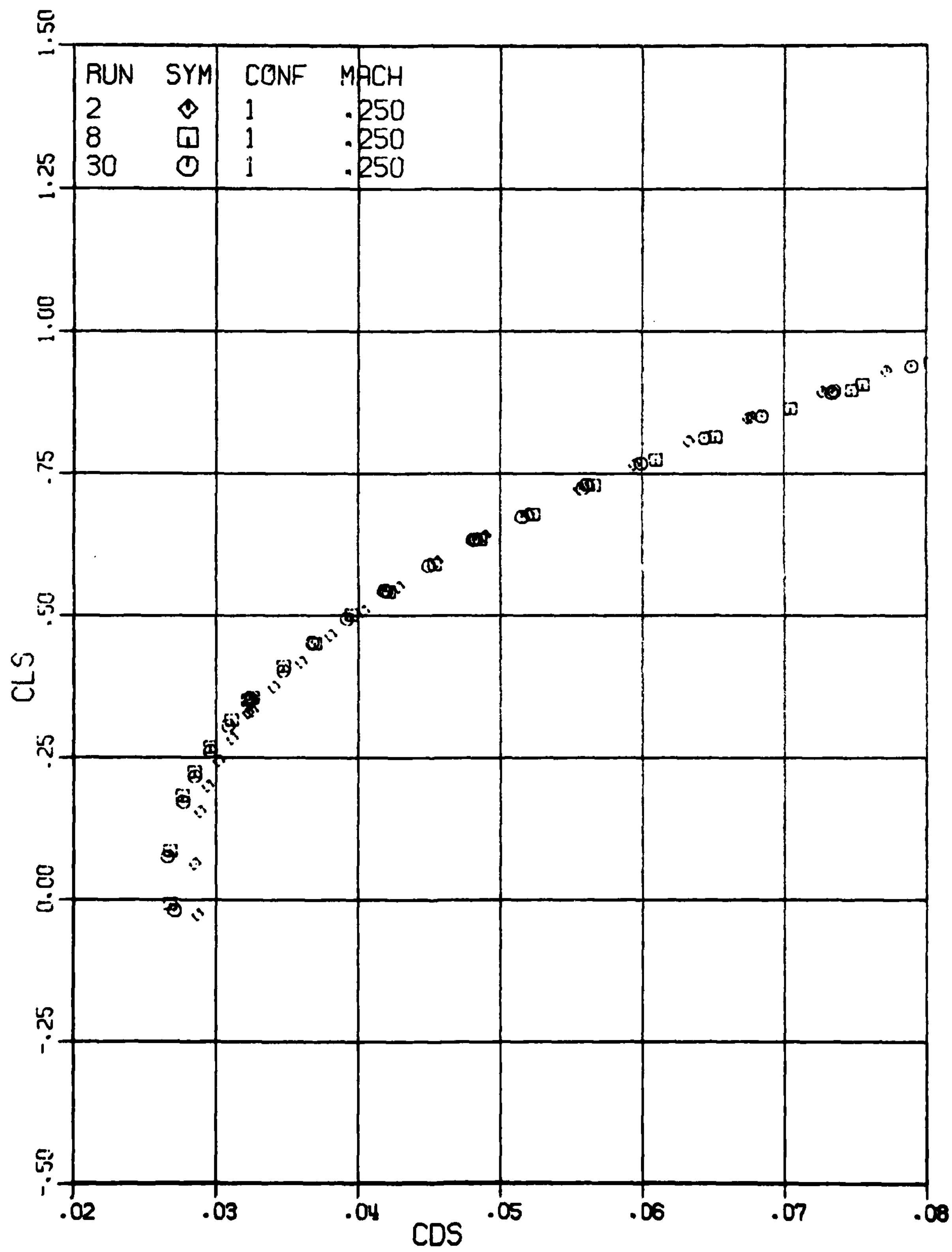
Figure 2 - Comparison of the Baseline Configuration and Configuration L_1

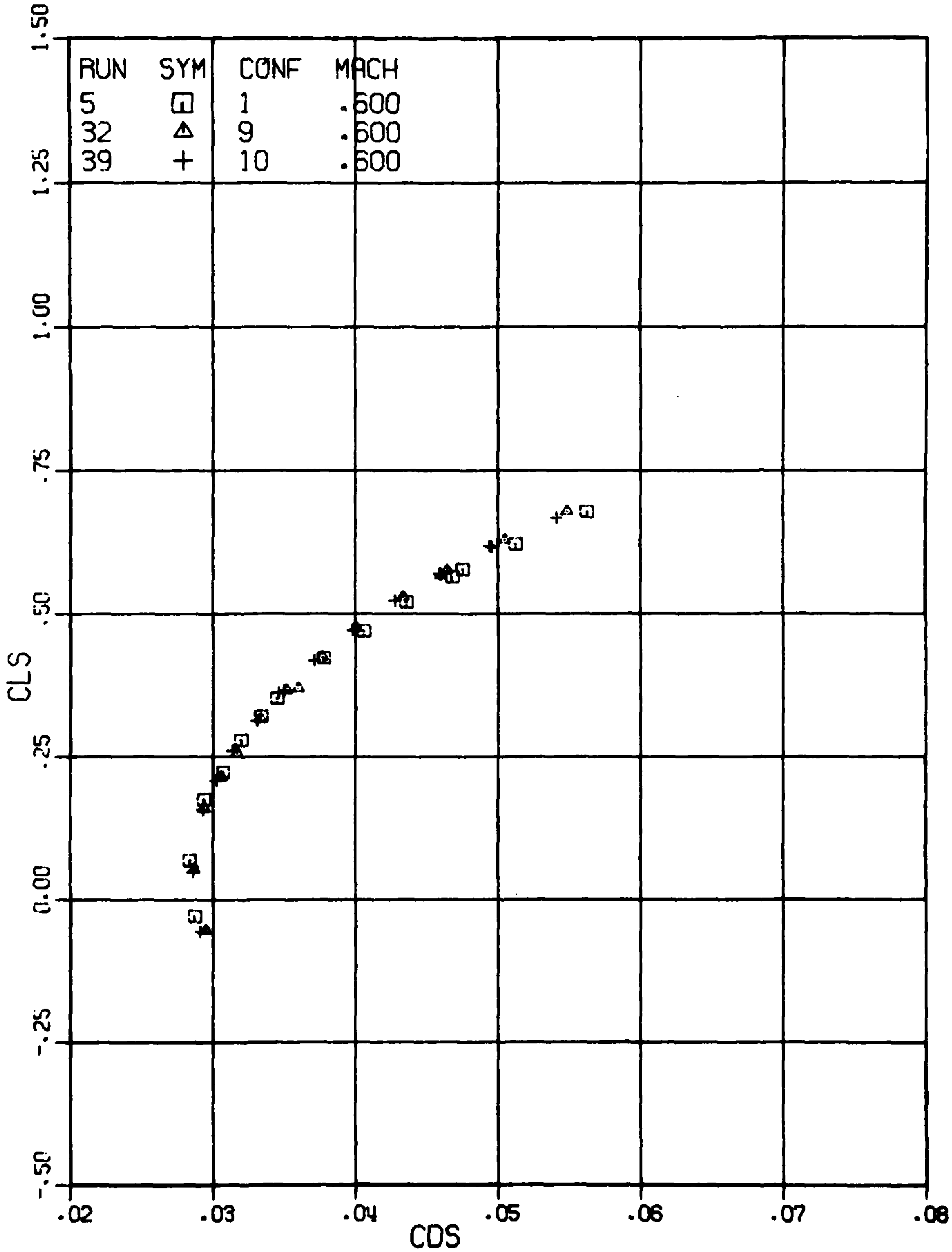
APPENDIX

DATA PLOTS

SECTION 1

LIFT COEFFICIENT VERSUS DRAG COEFFICIENT

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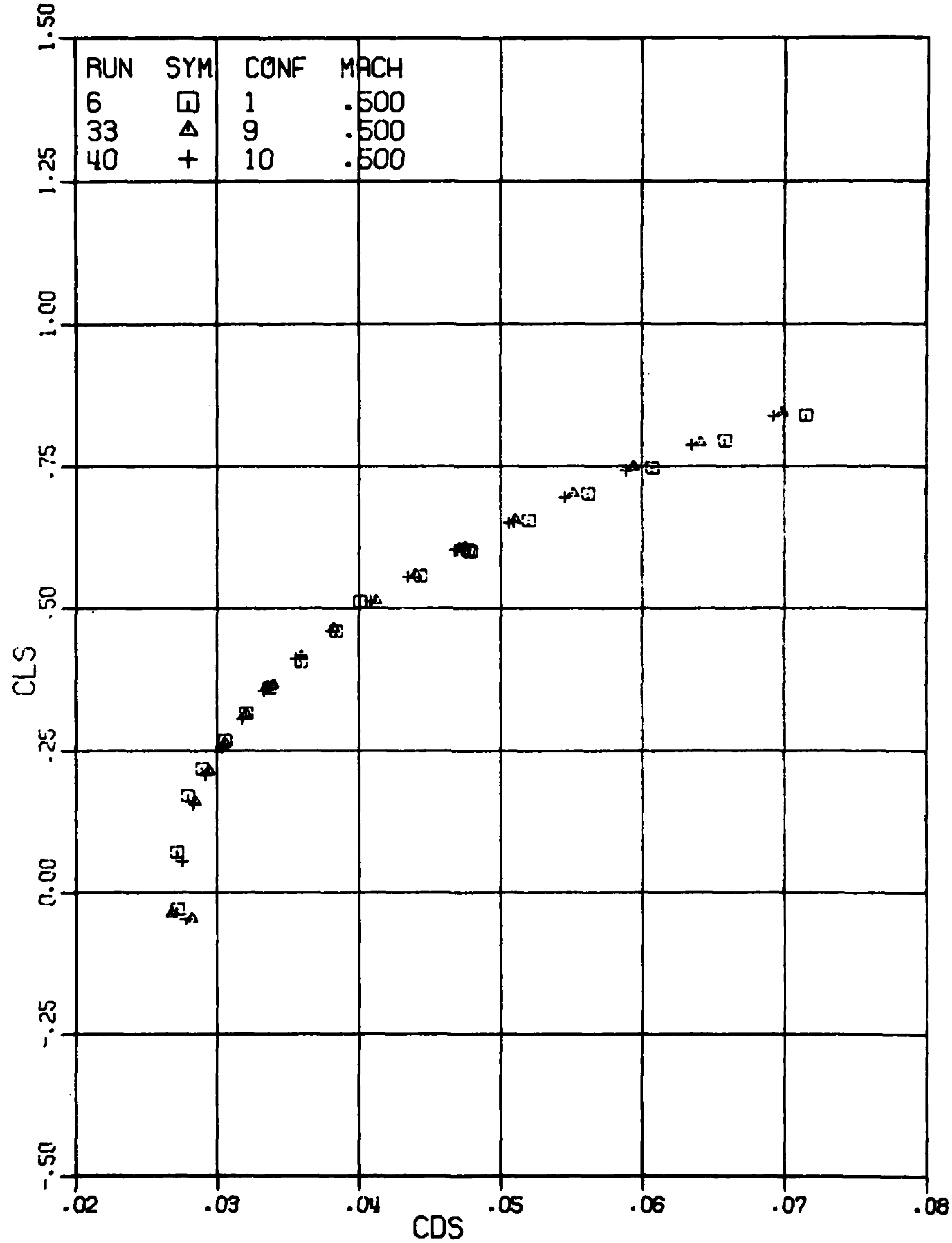

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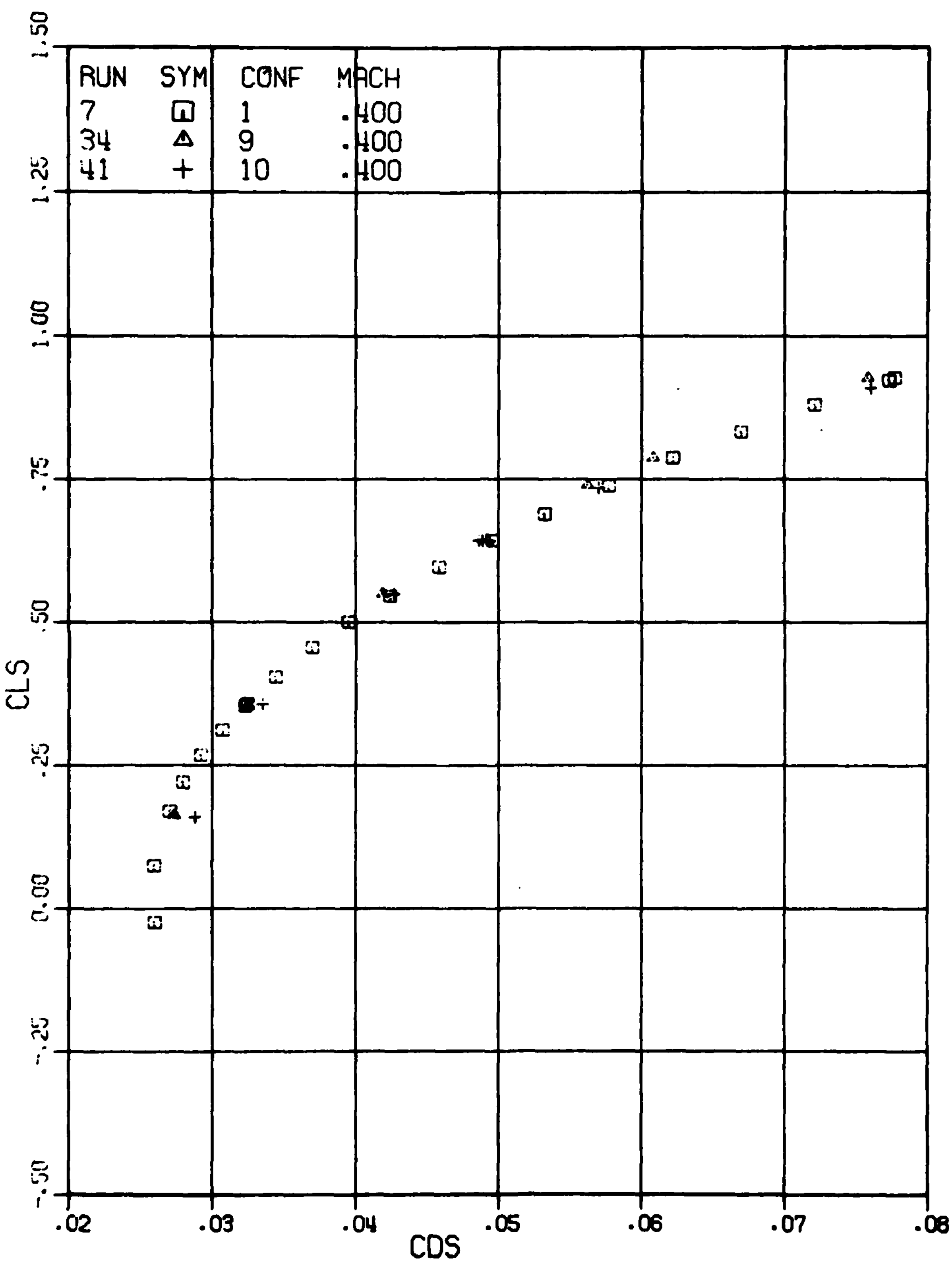
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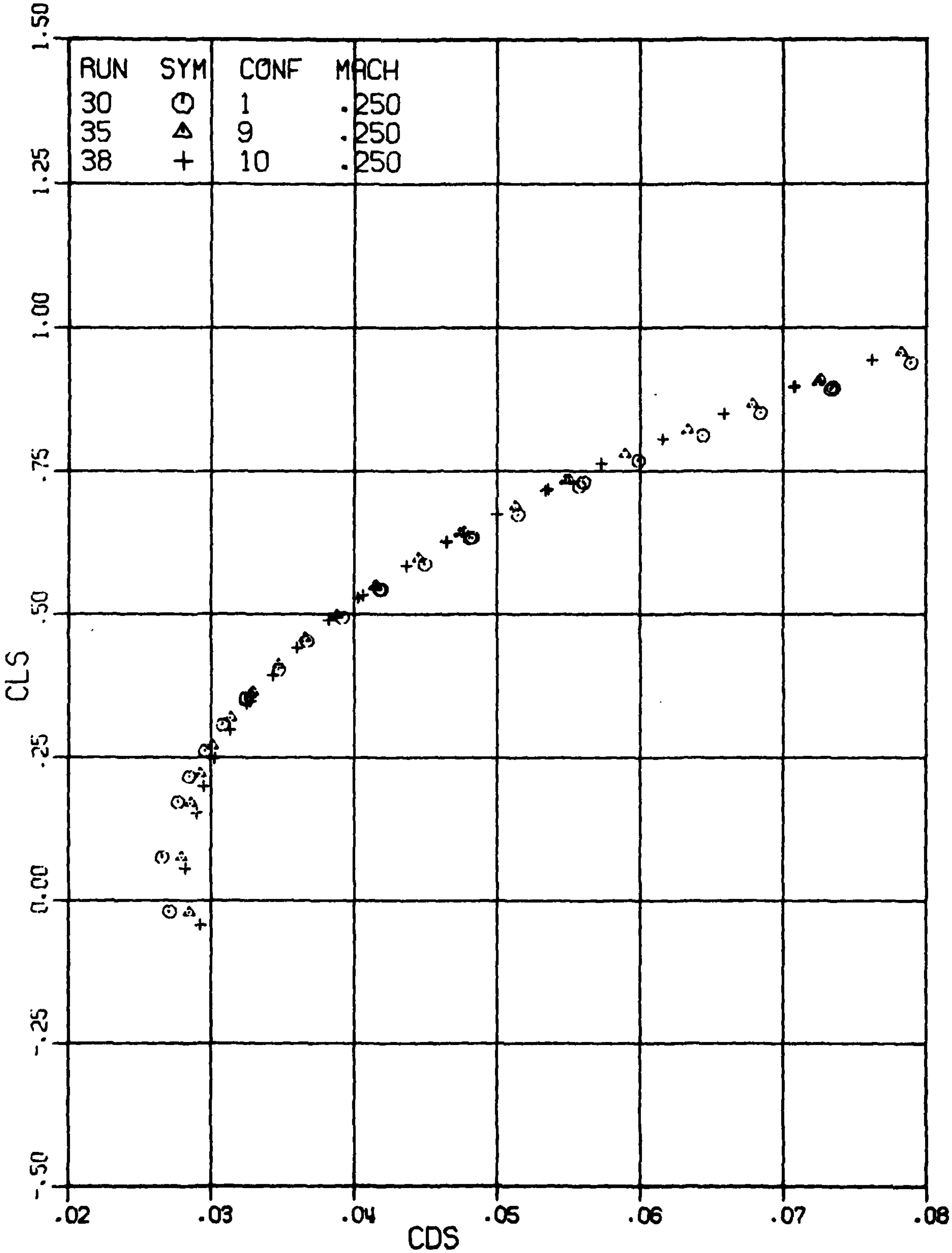
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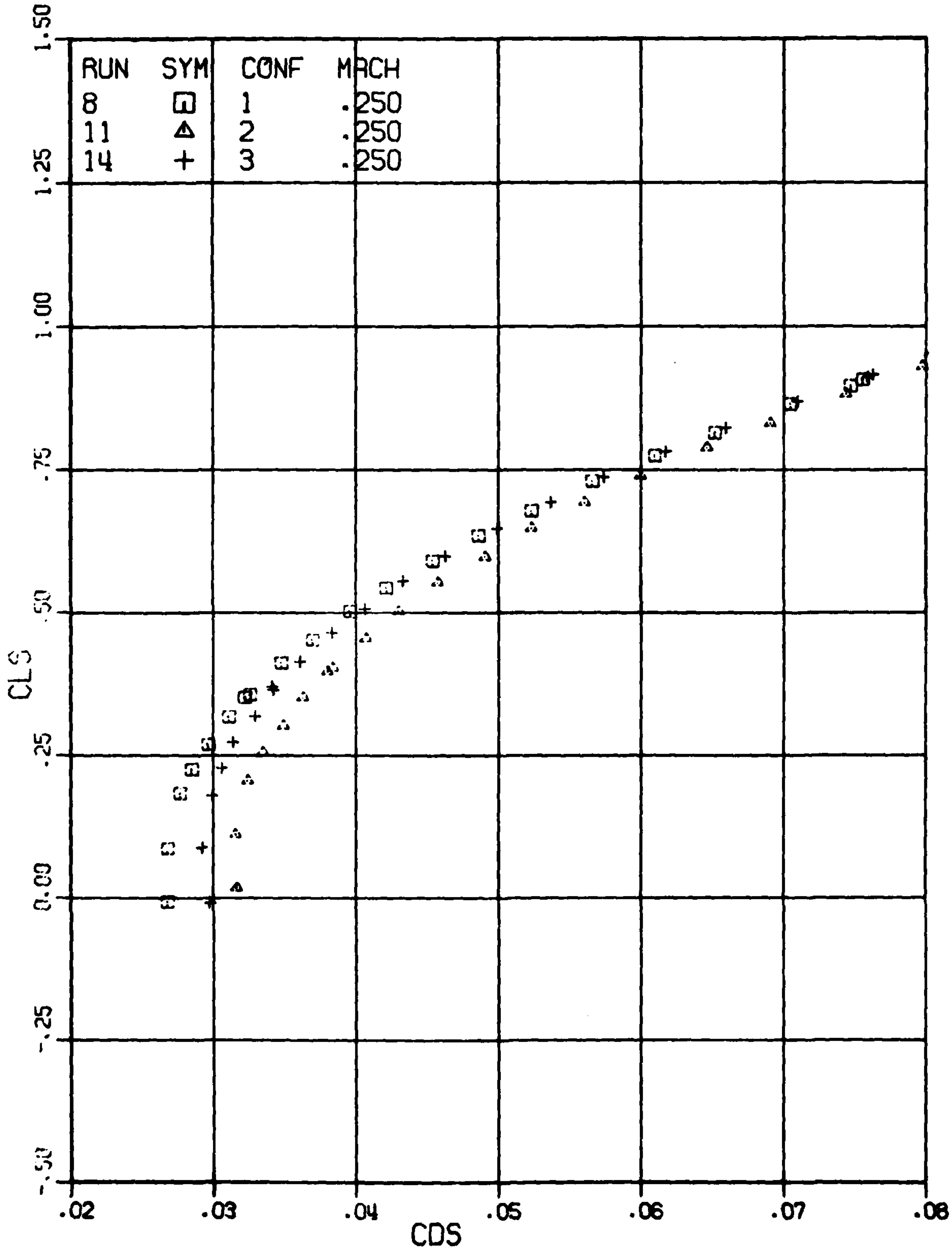

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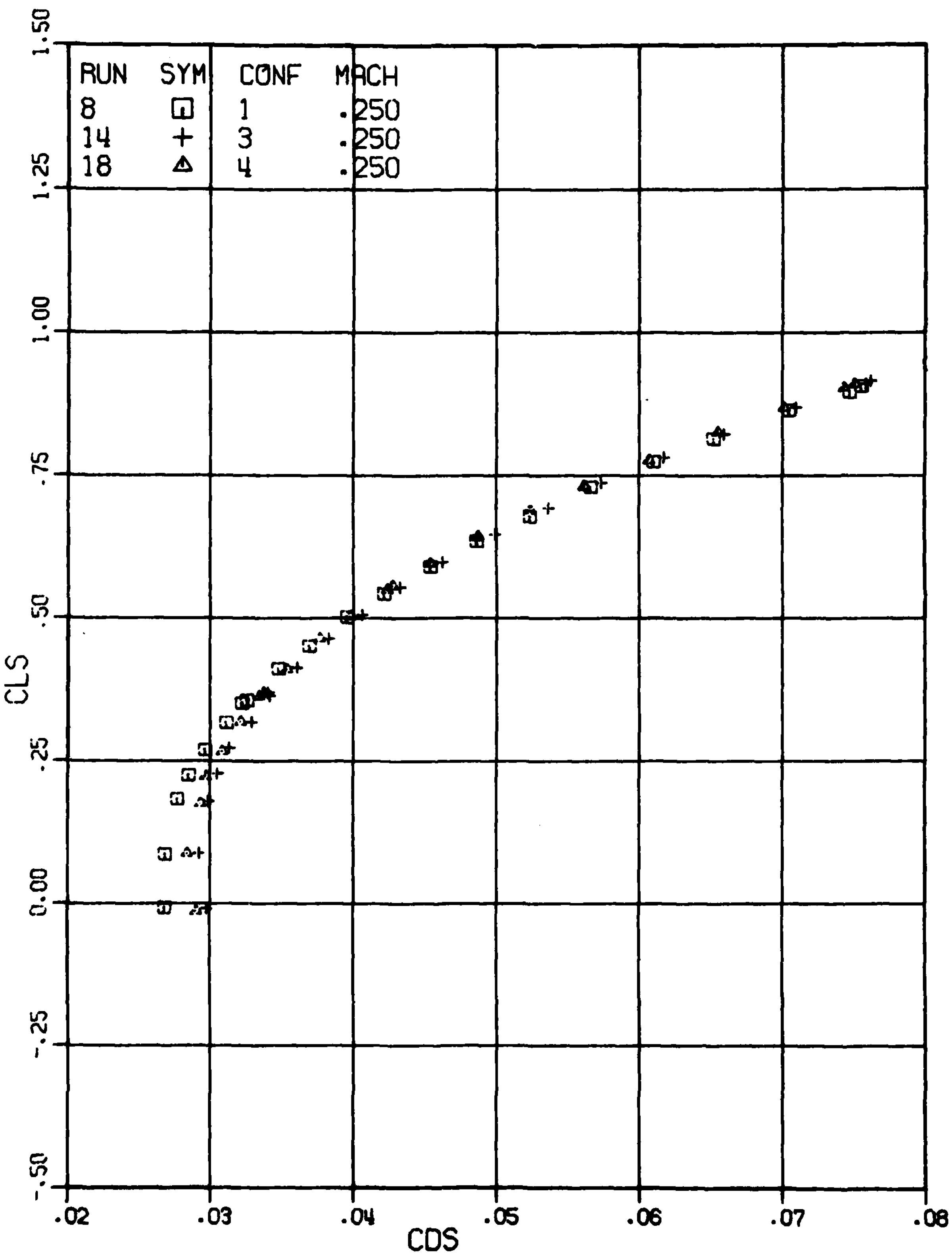
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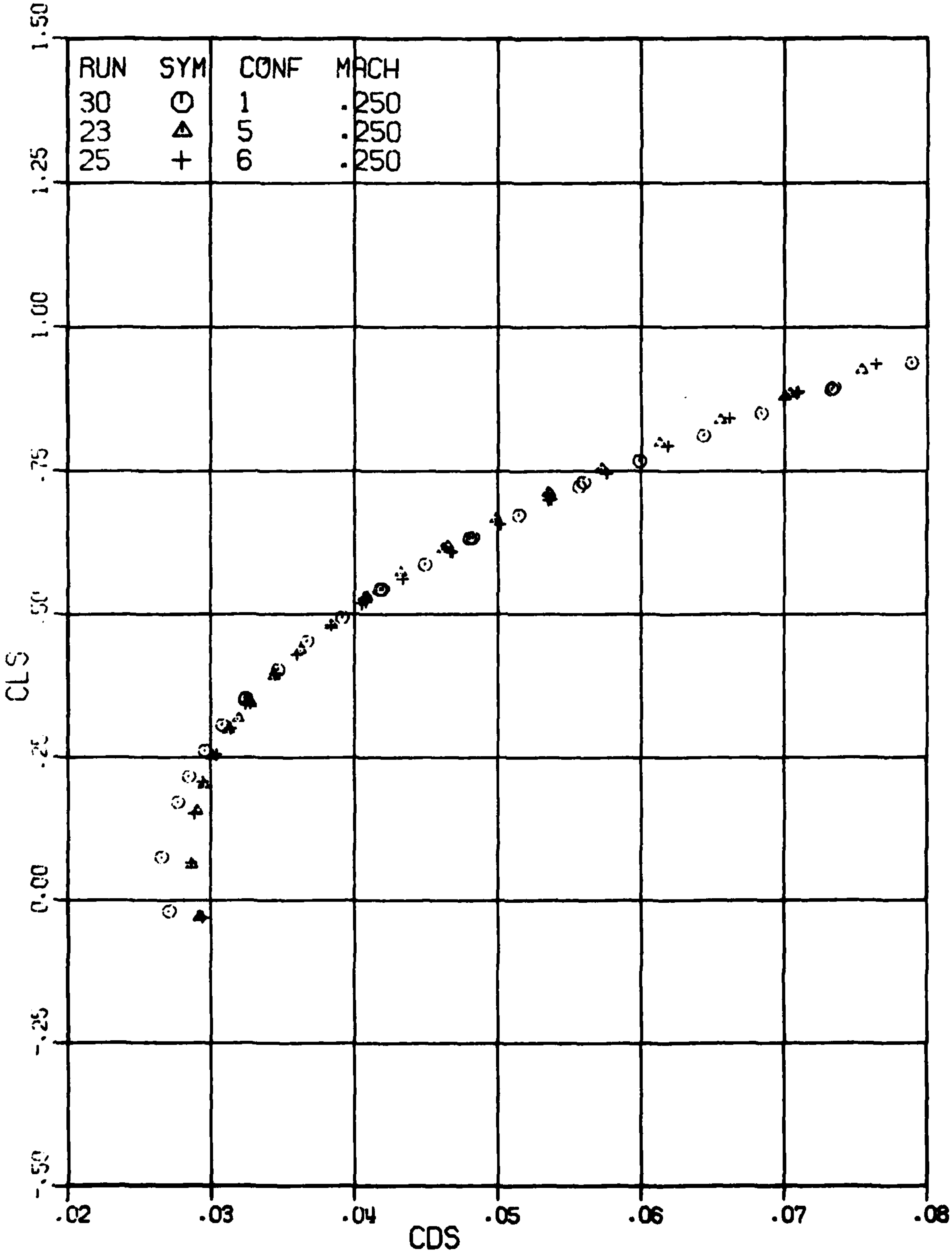
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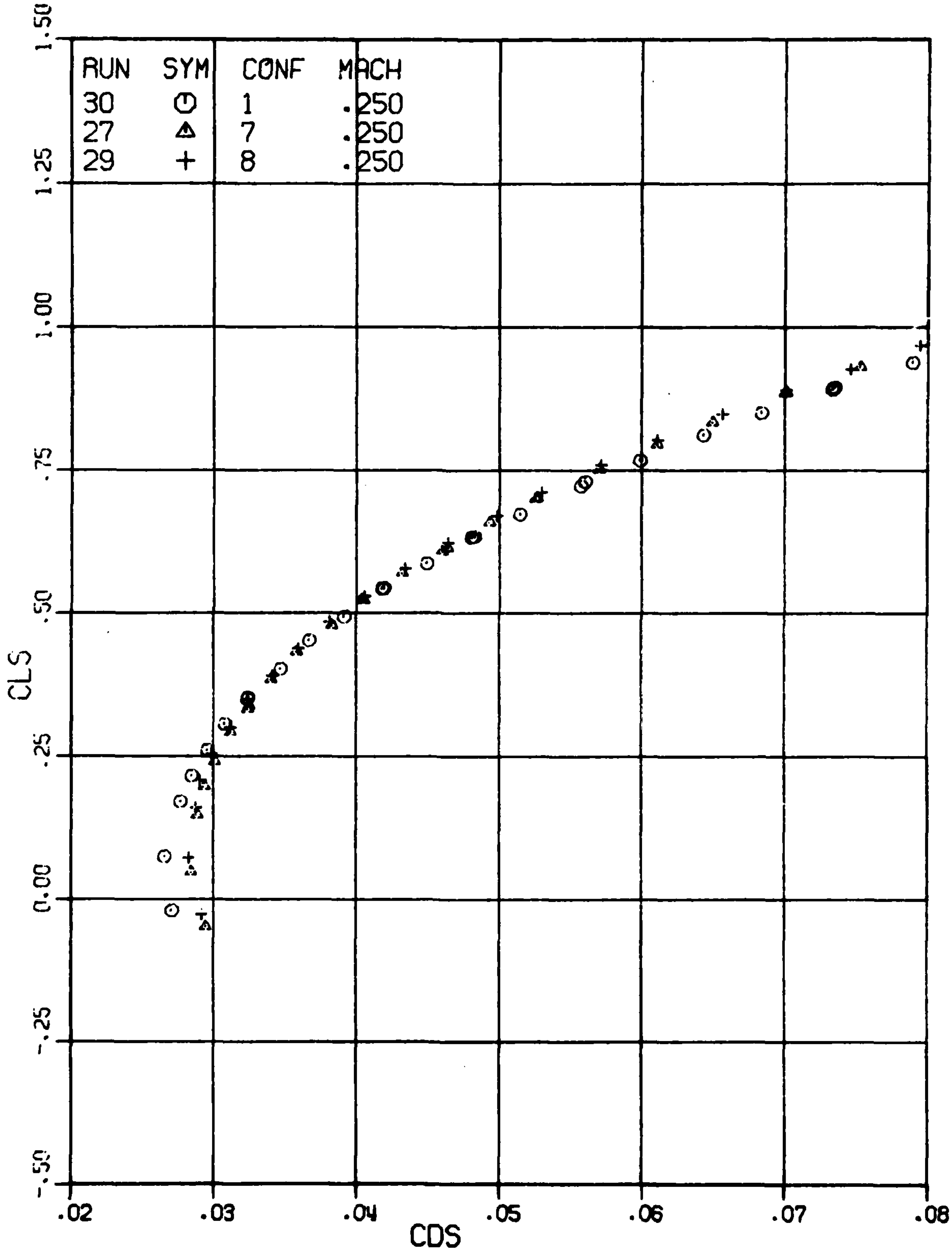
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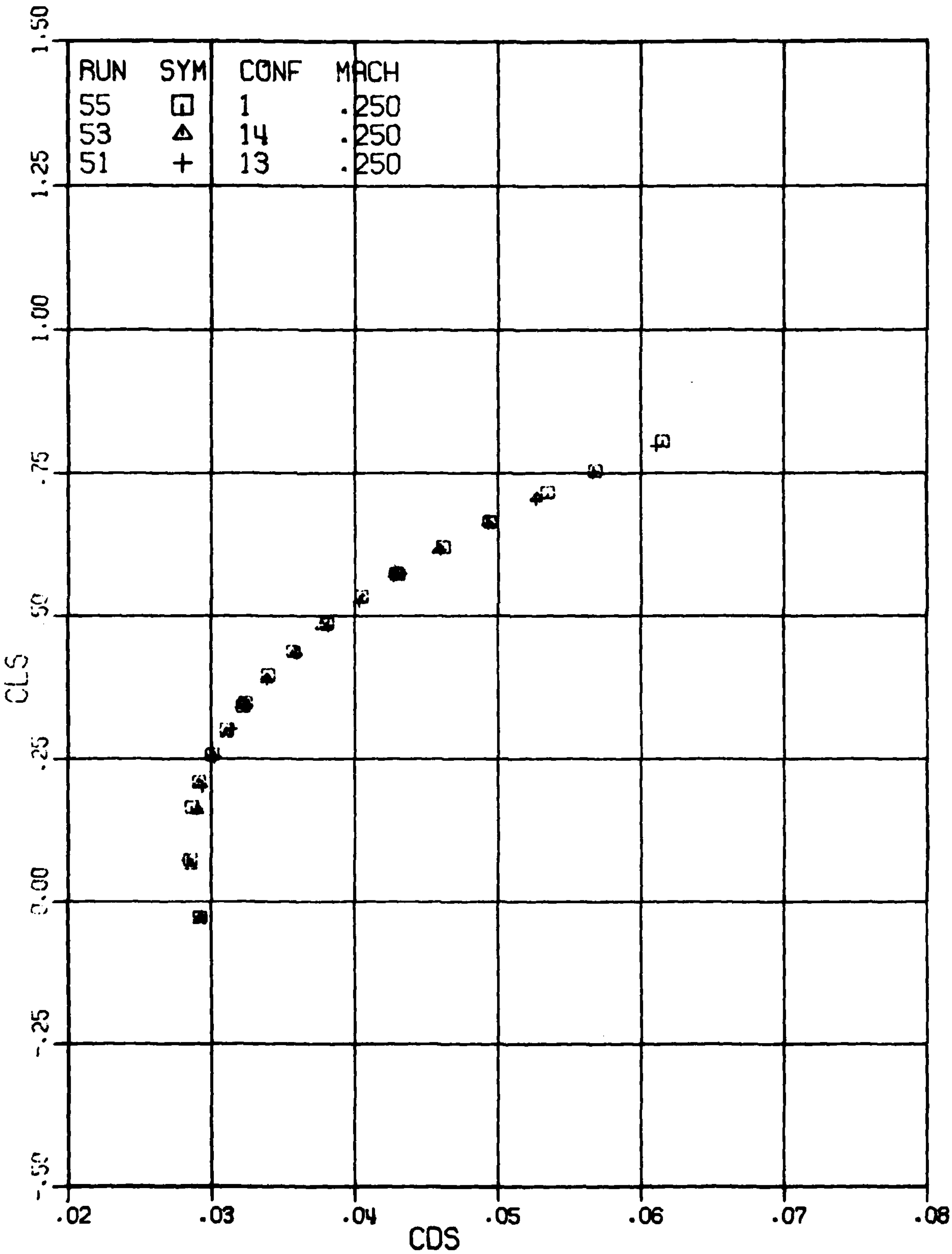
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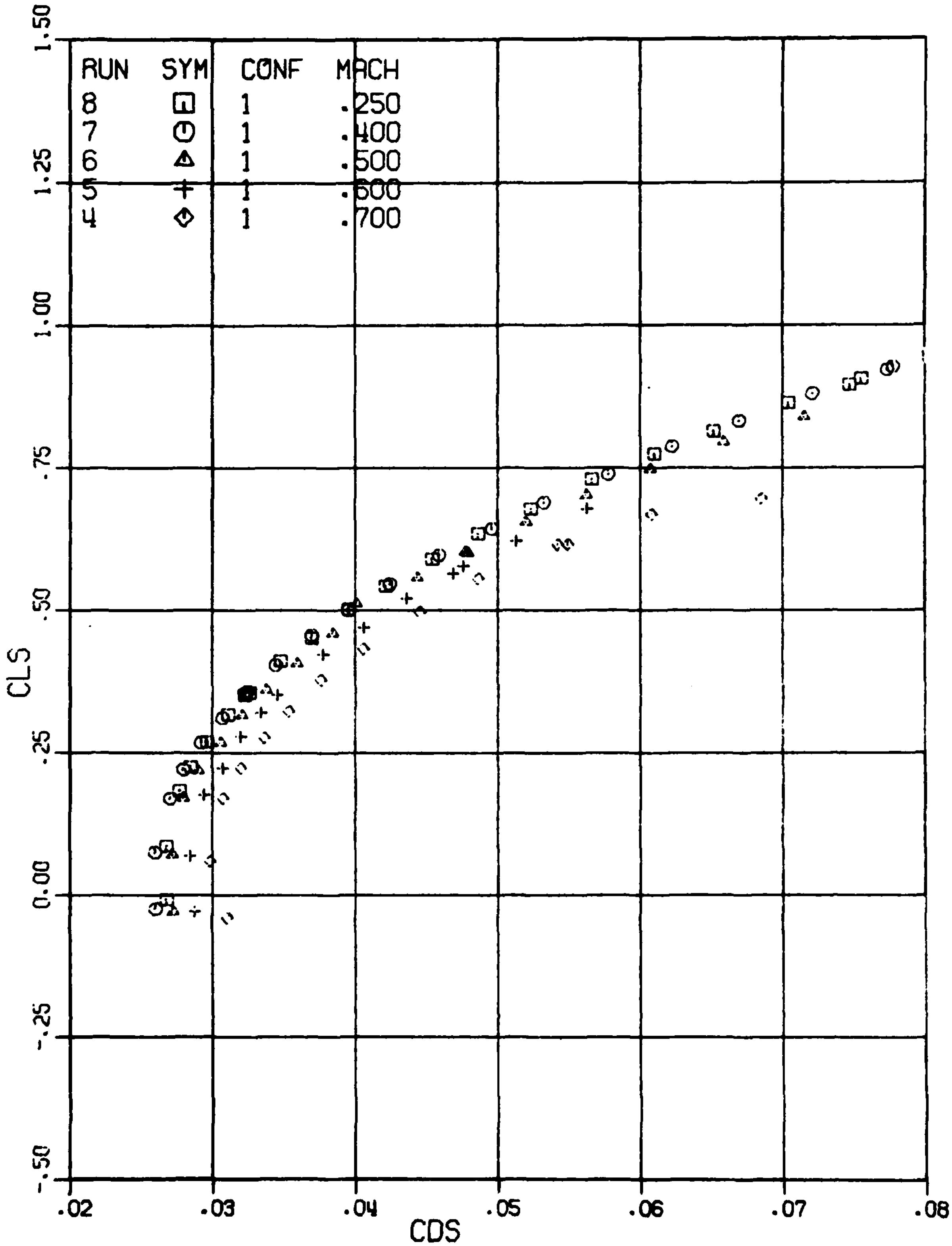
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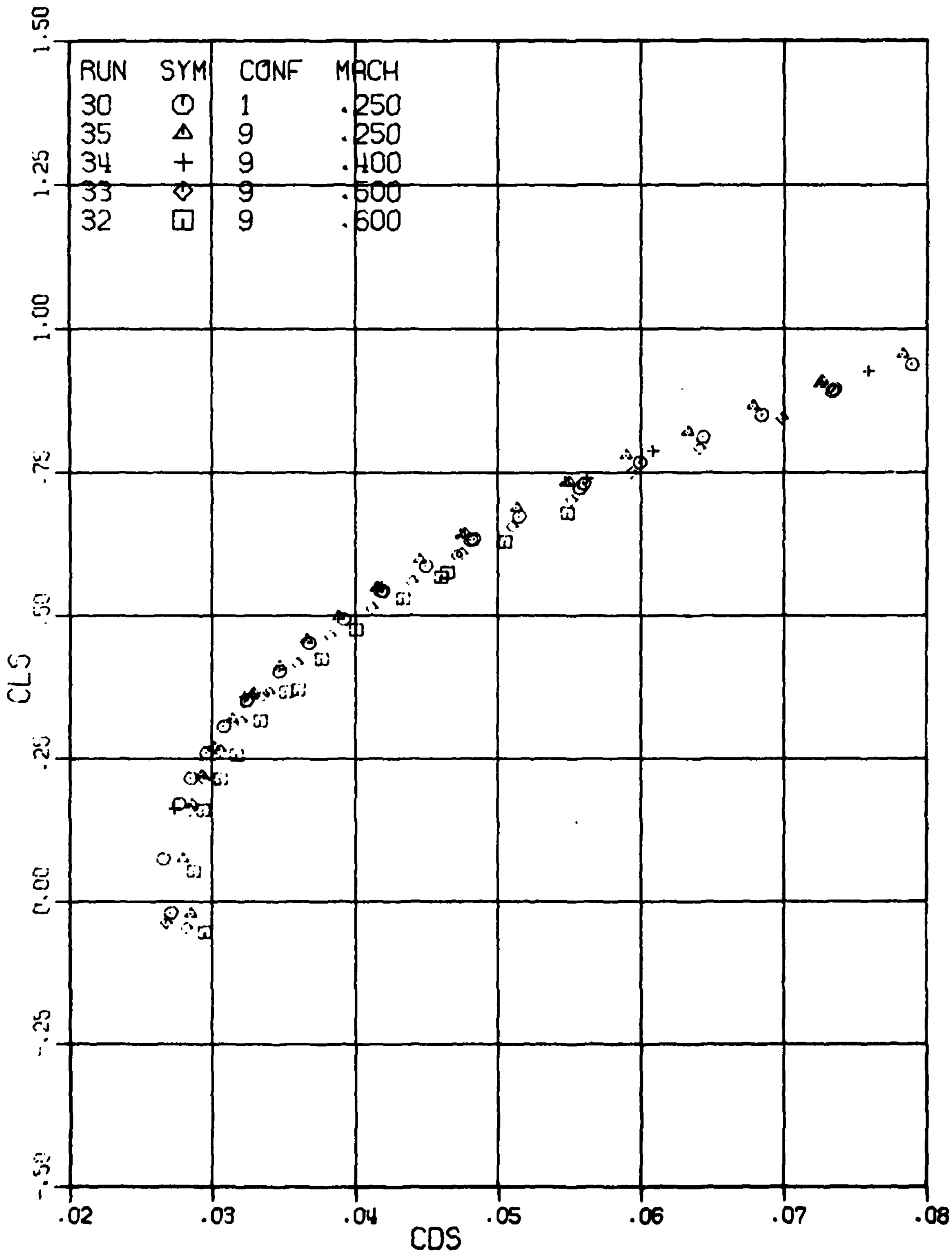
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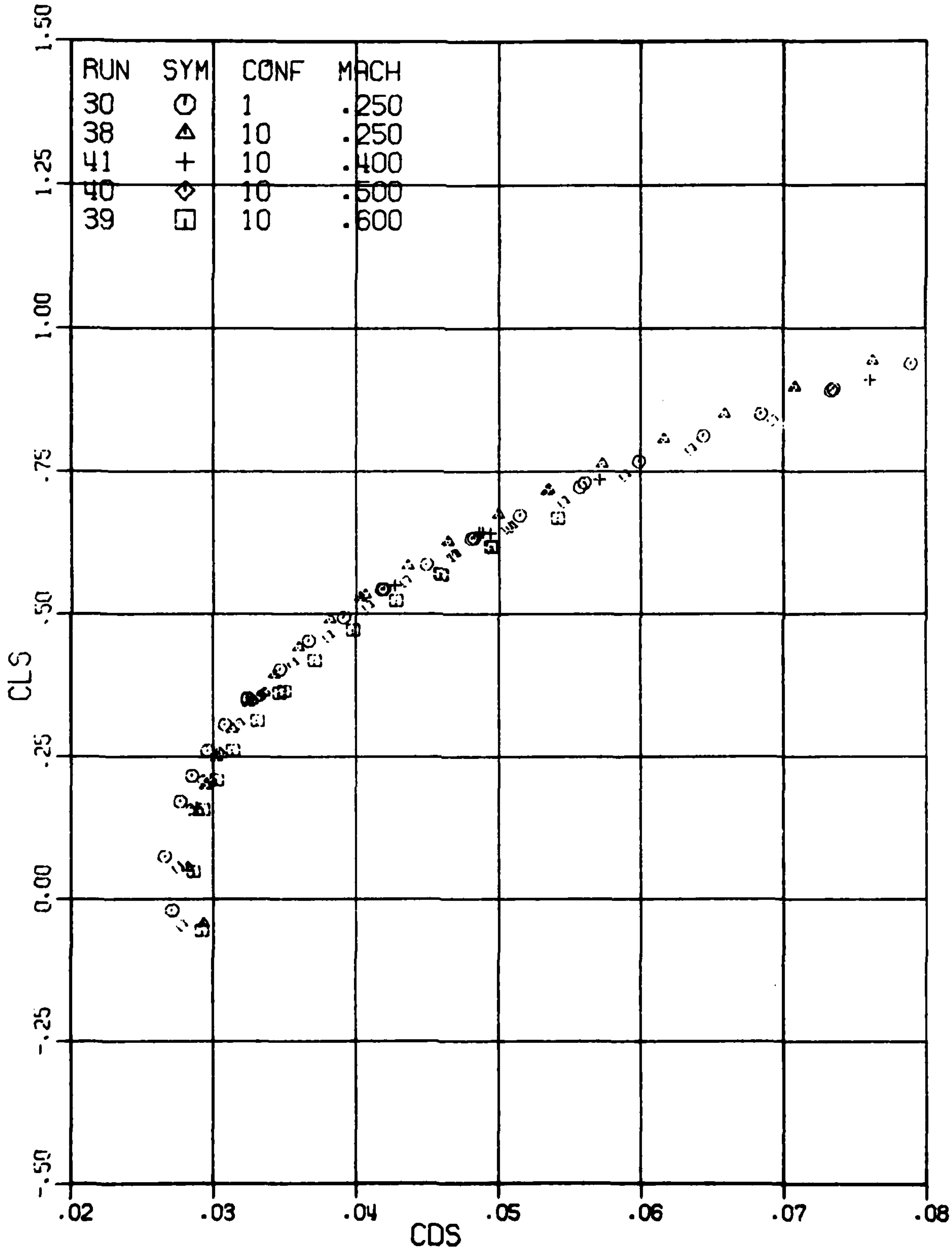

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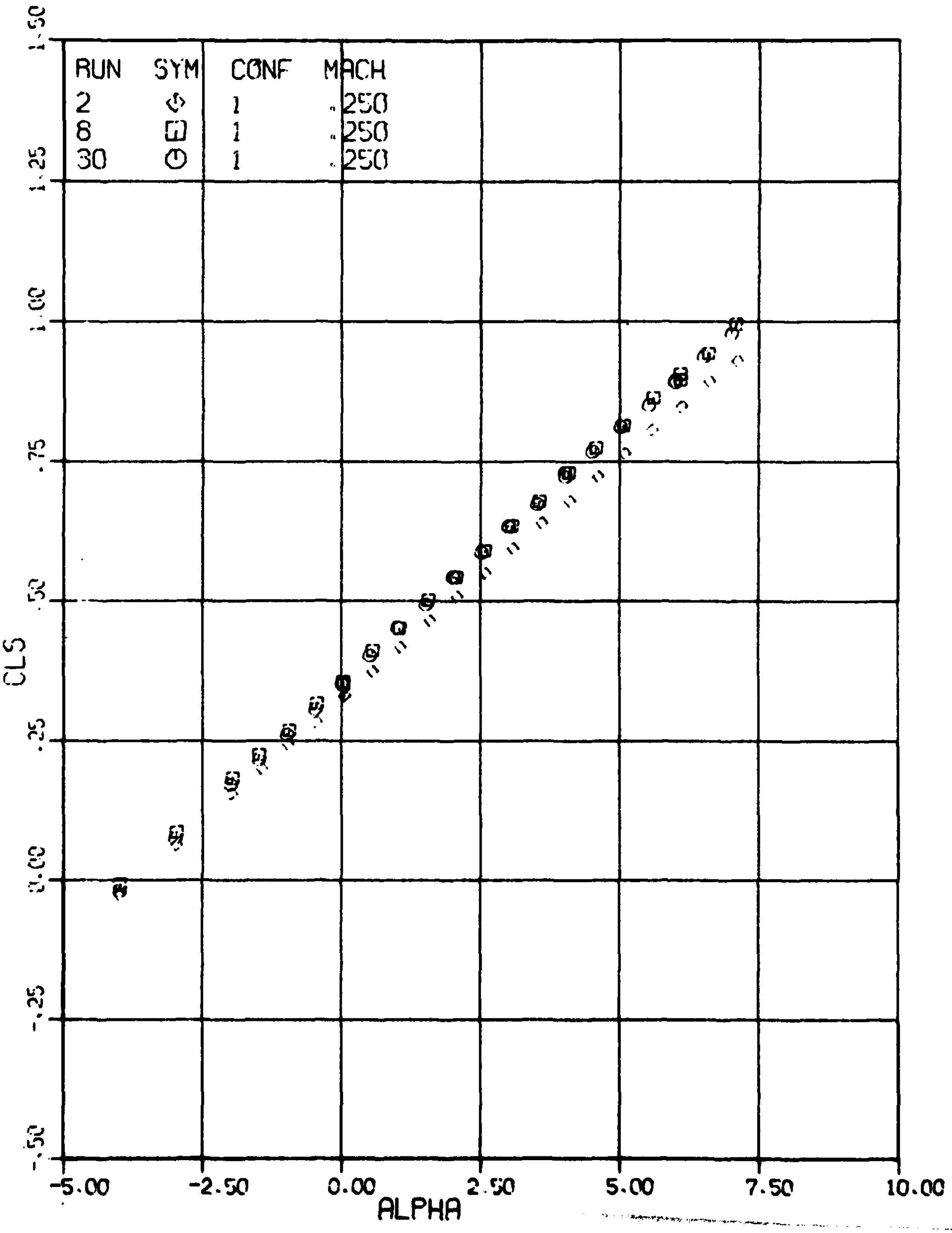
SECTION 2

LIFT COEFFICIENT VERSUS ALPHA



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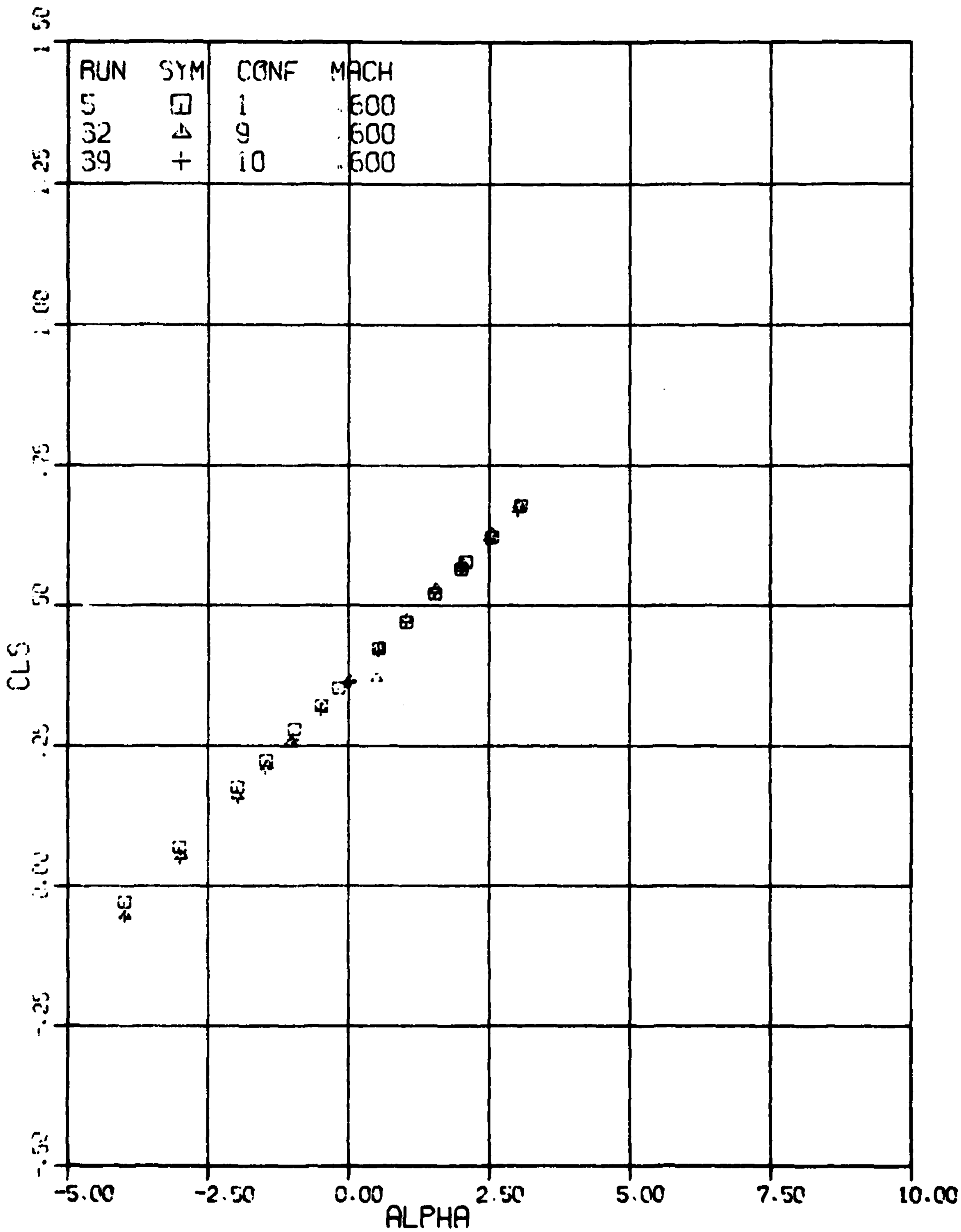
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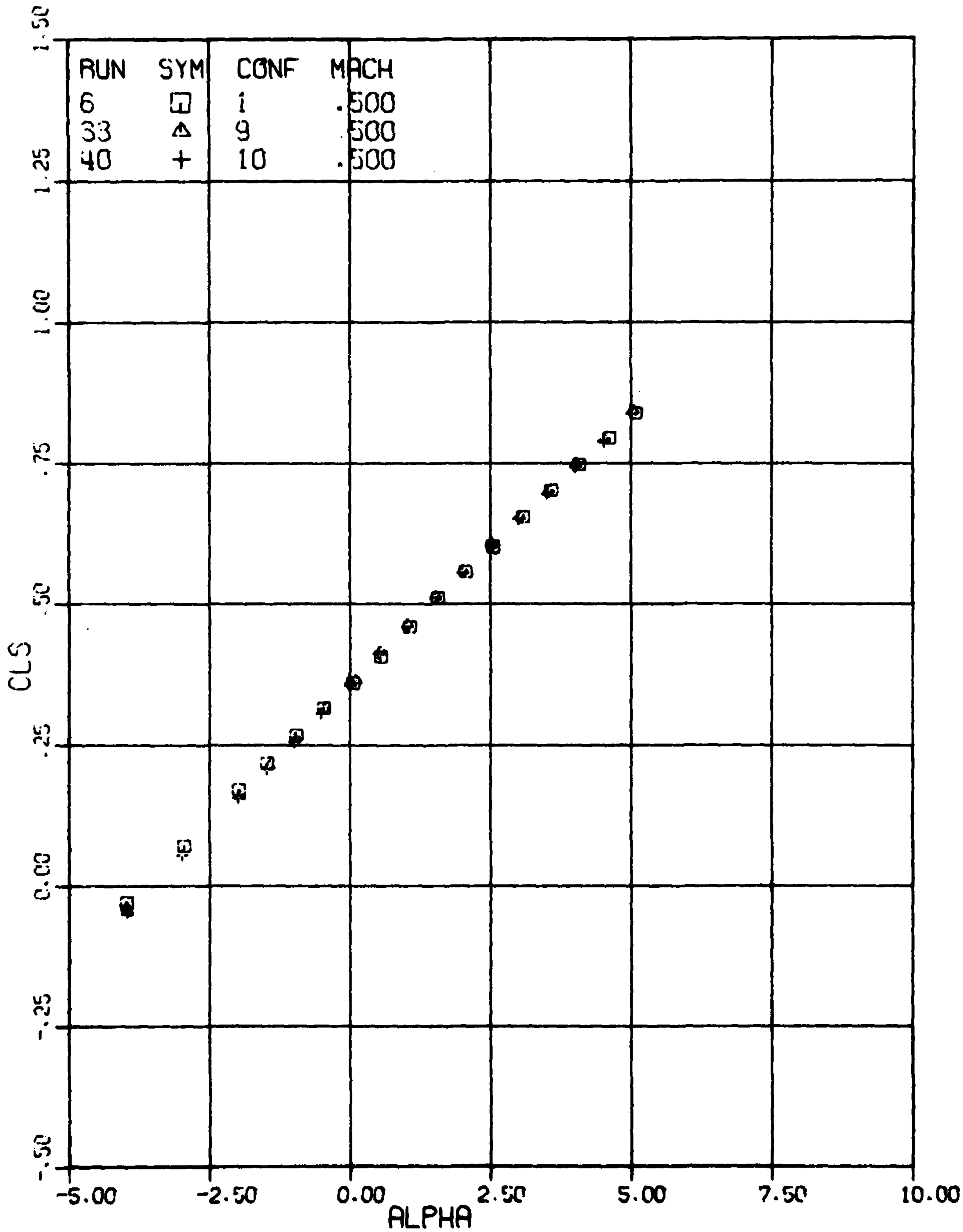

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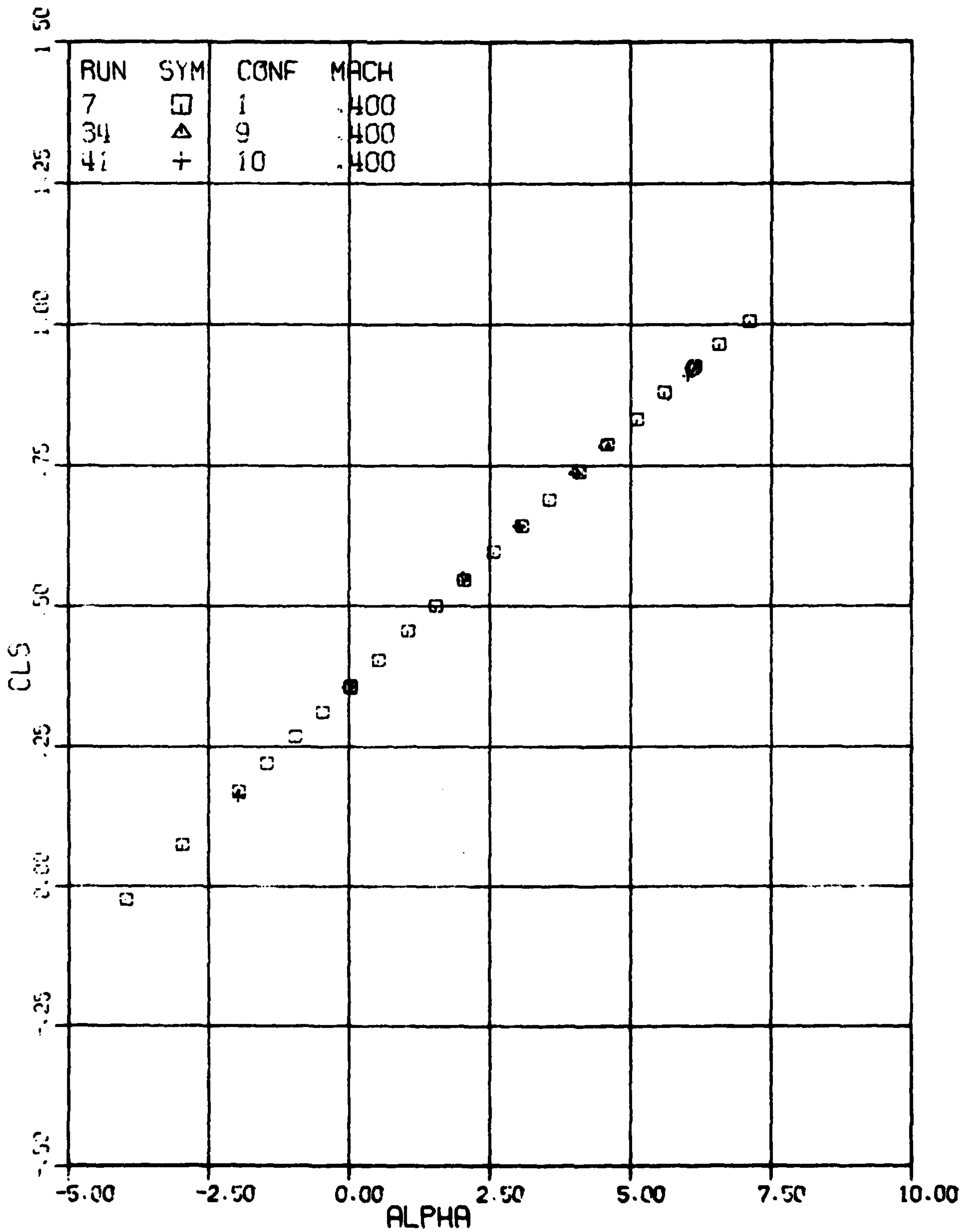
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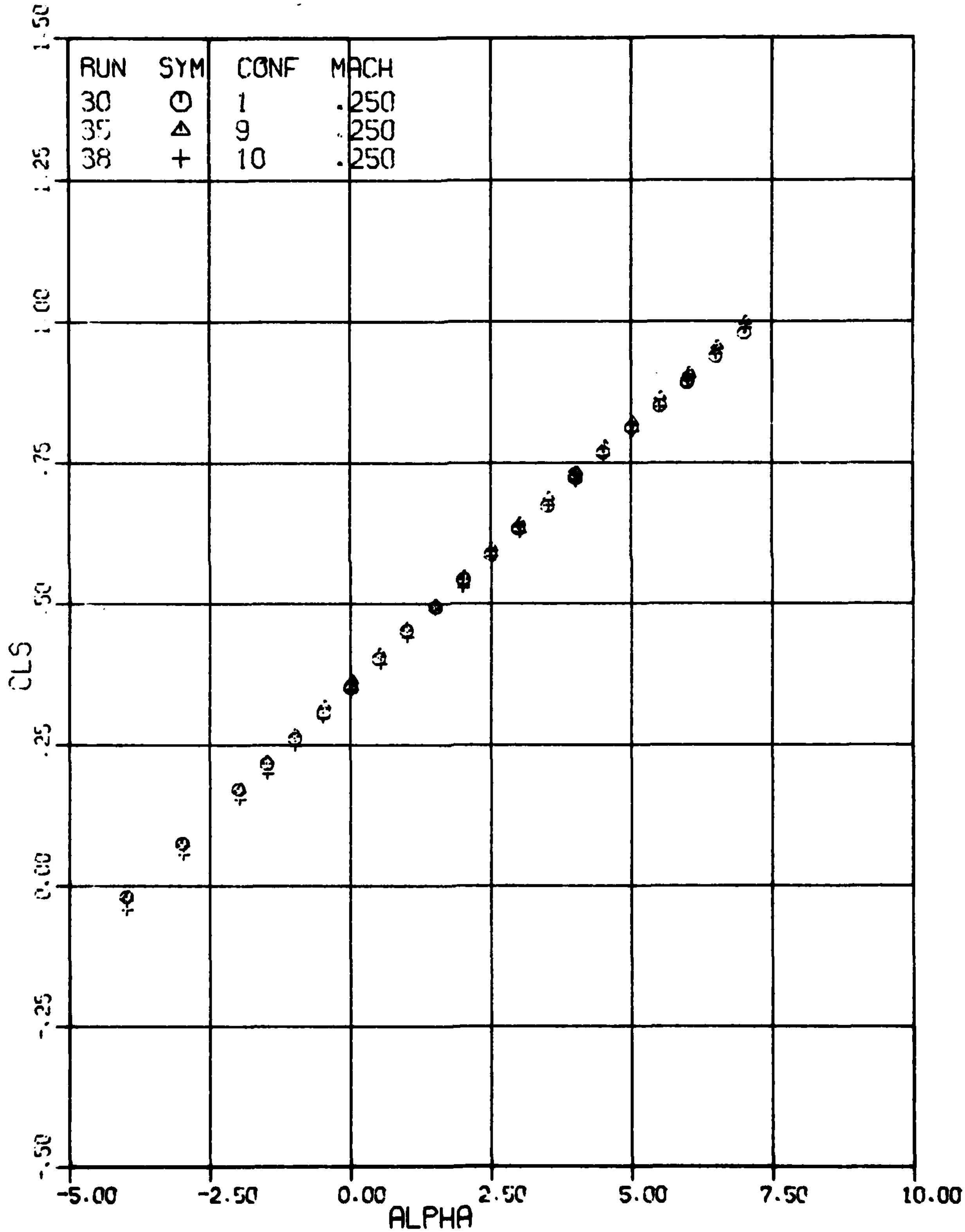
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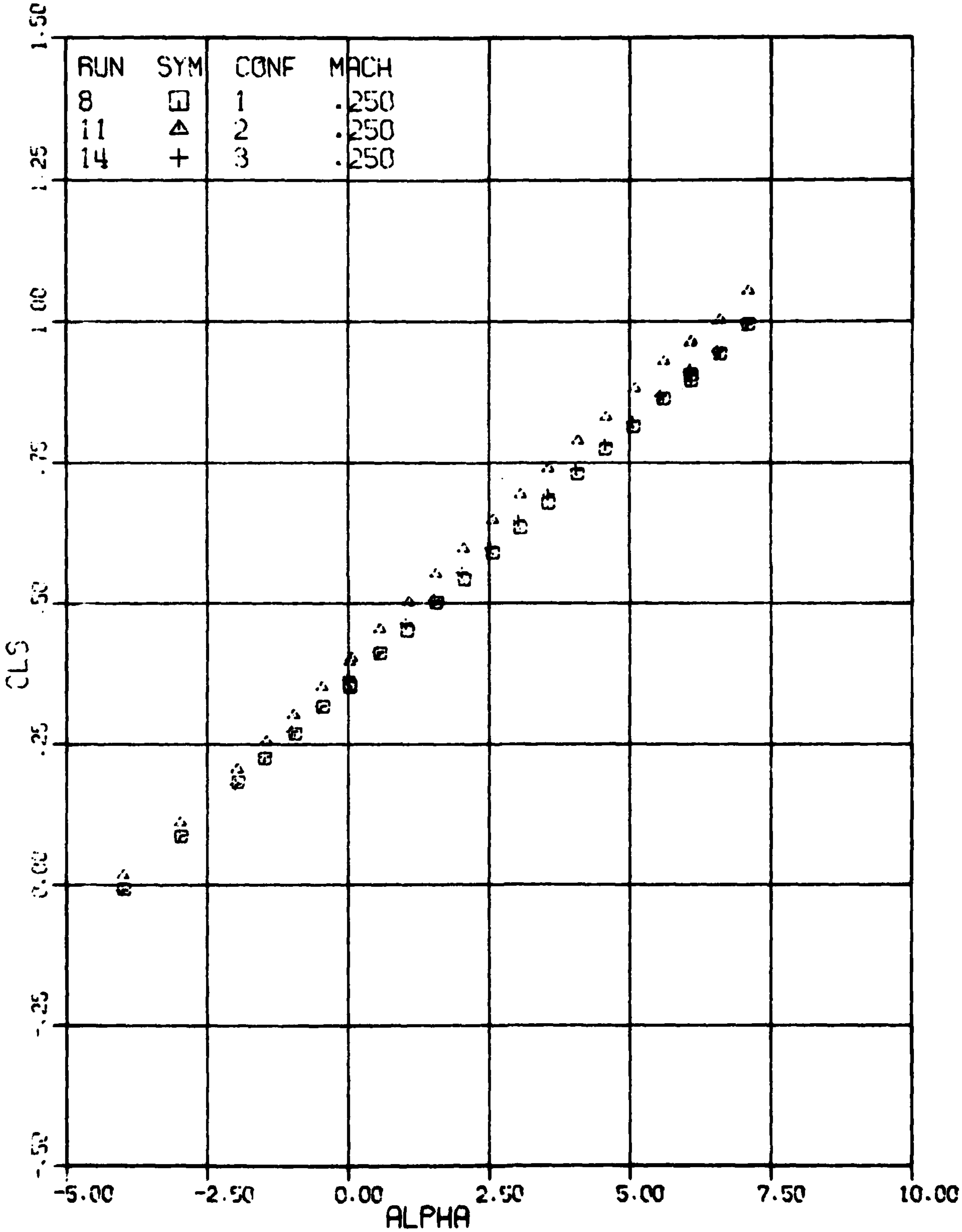
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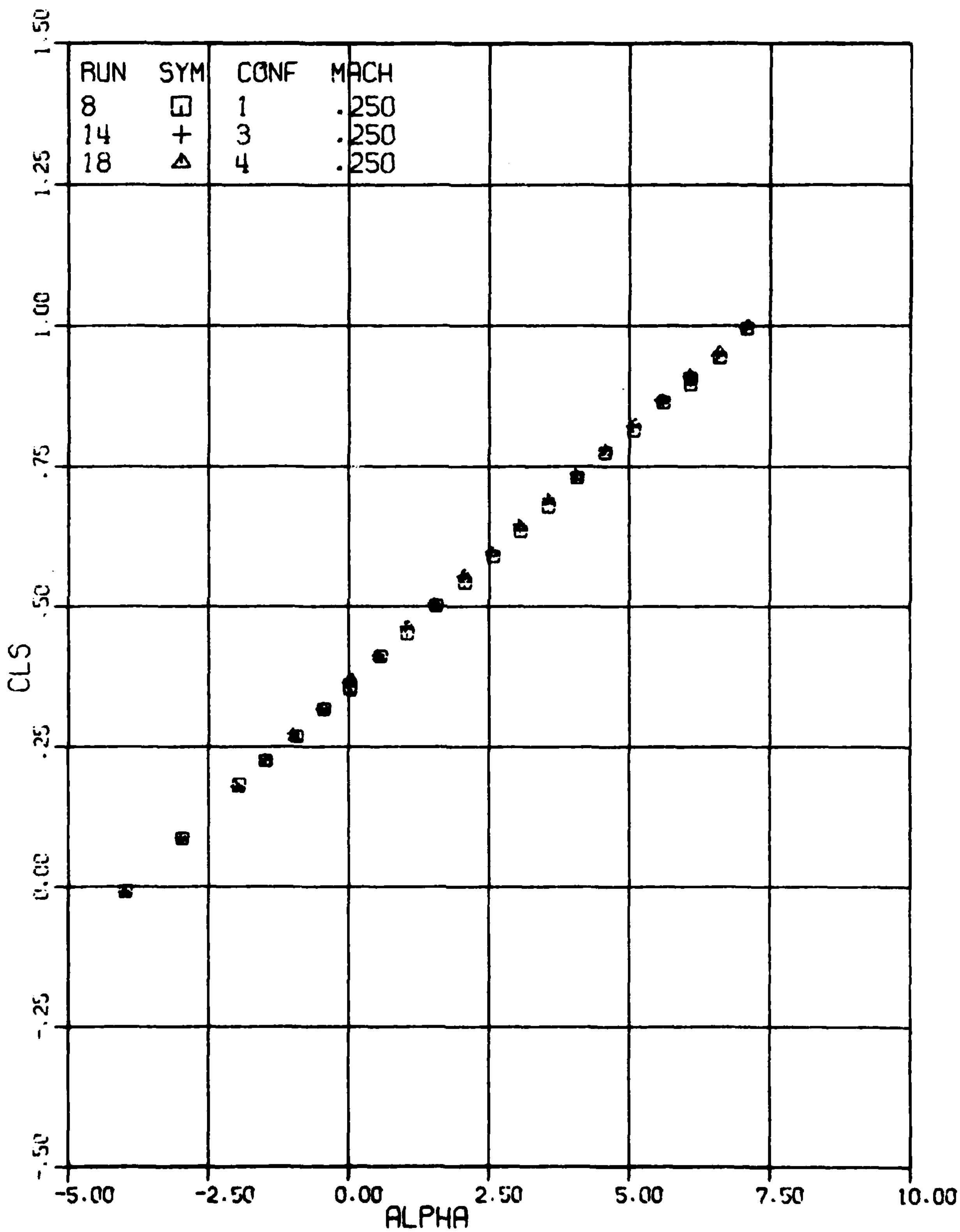

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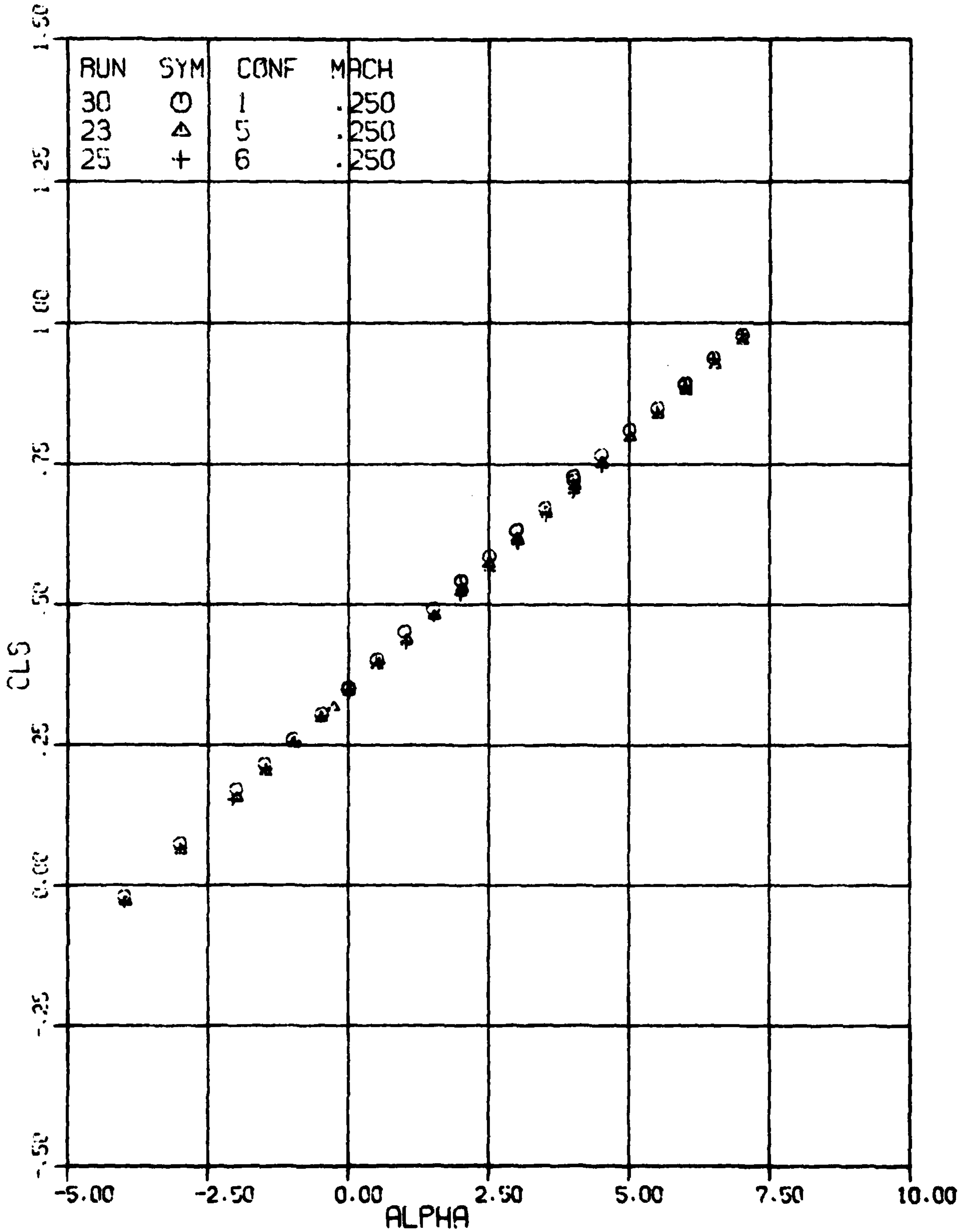
14 + 3 .250
18 △ 4 .250
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
CLS
-5.00
-2.50
0.00
2.50
5.00
7.50
10.00
ALPHA


RUN SYM CONF MACH
30 O 1 .250
23 △ 5 .250
25 + 6 .250
CLS
ALPHA
1.50
1.25
1.00
.75
.50
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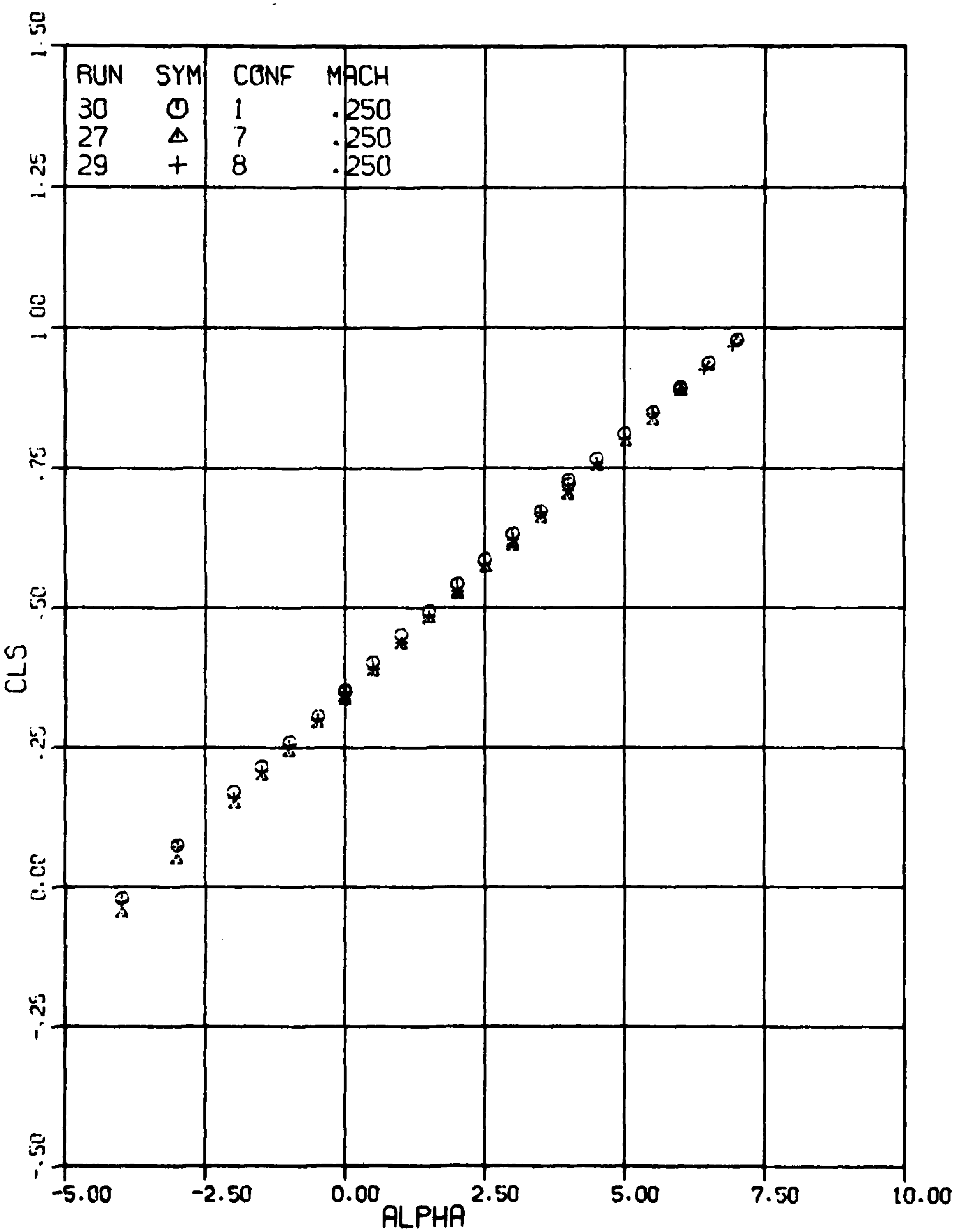
-.25
-.50
-5.00
-2.50
0.00
2.50
5.00
7.50
10.00


RUN SYM CONF MACH
30 O 1 .250
27 △ 7 .250
29 + 8 .250
1.50
1.25
1.00
.75
.50
.25
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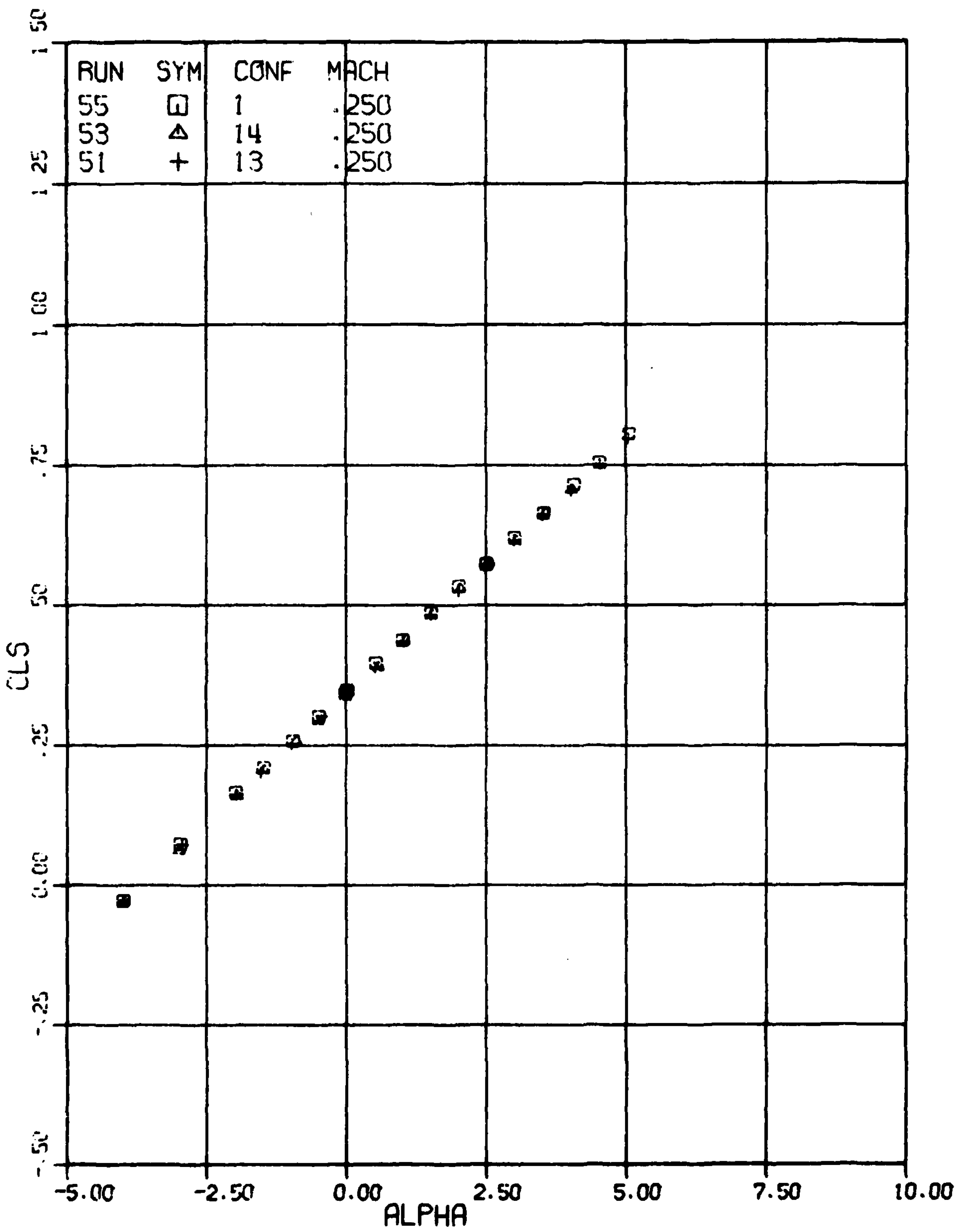
-.50
CLS
-5.00
-2.50
0.00
2.50
5.00
7.50
10.00
ALPHA


RUN SYM CONF MACH
55 1 .250
53 14 .250
51 13 .250
CLS
ALPHA
1.50
1.25
1.00
.75
.50
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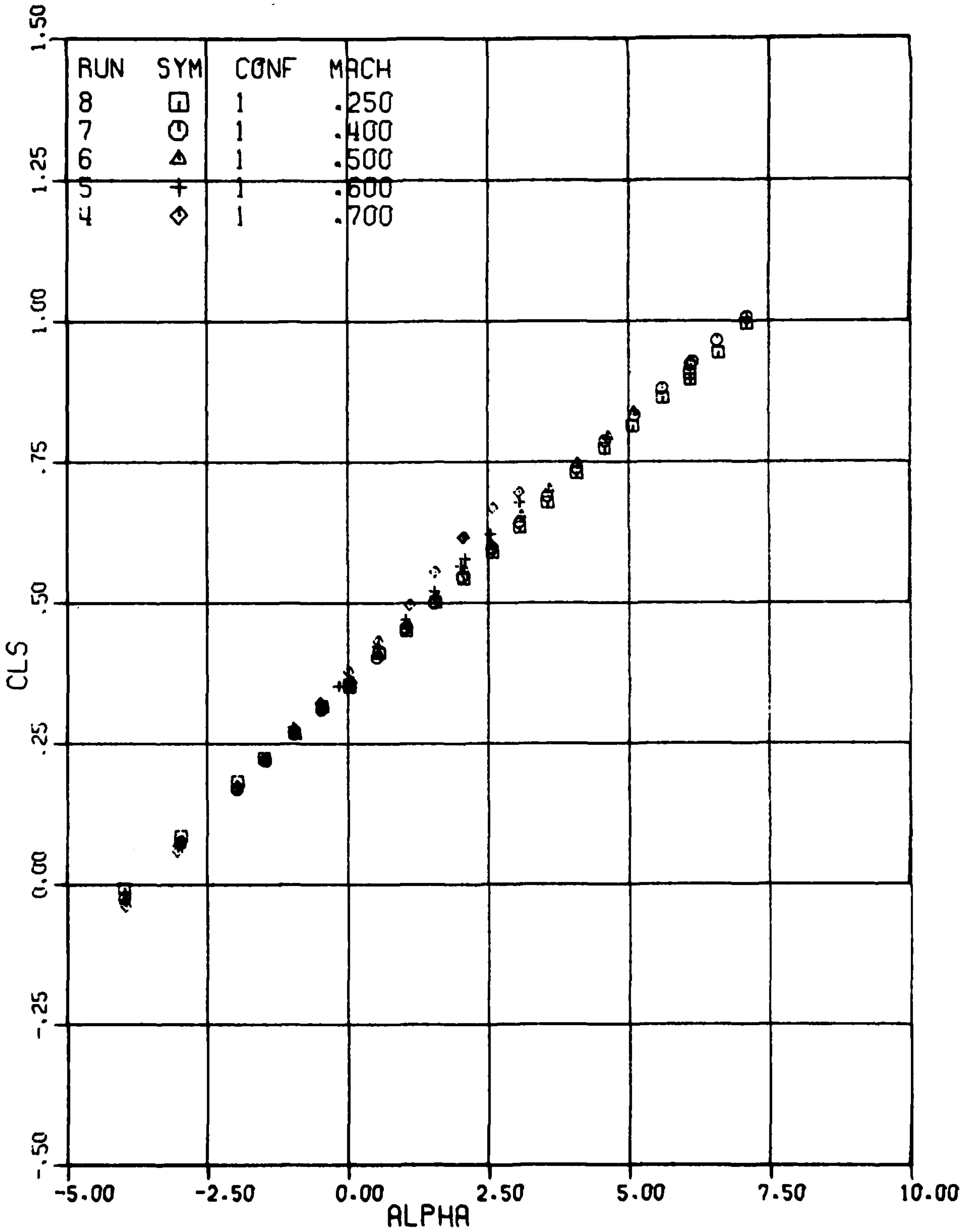
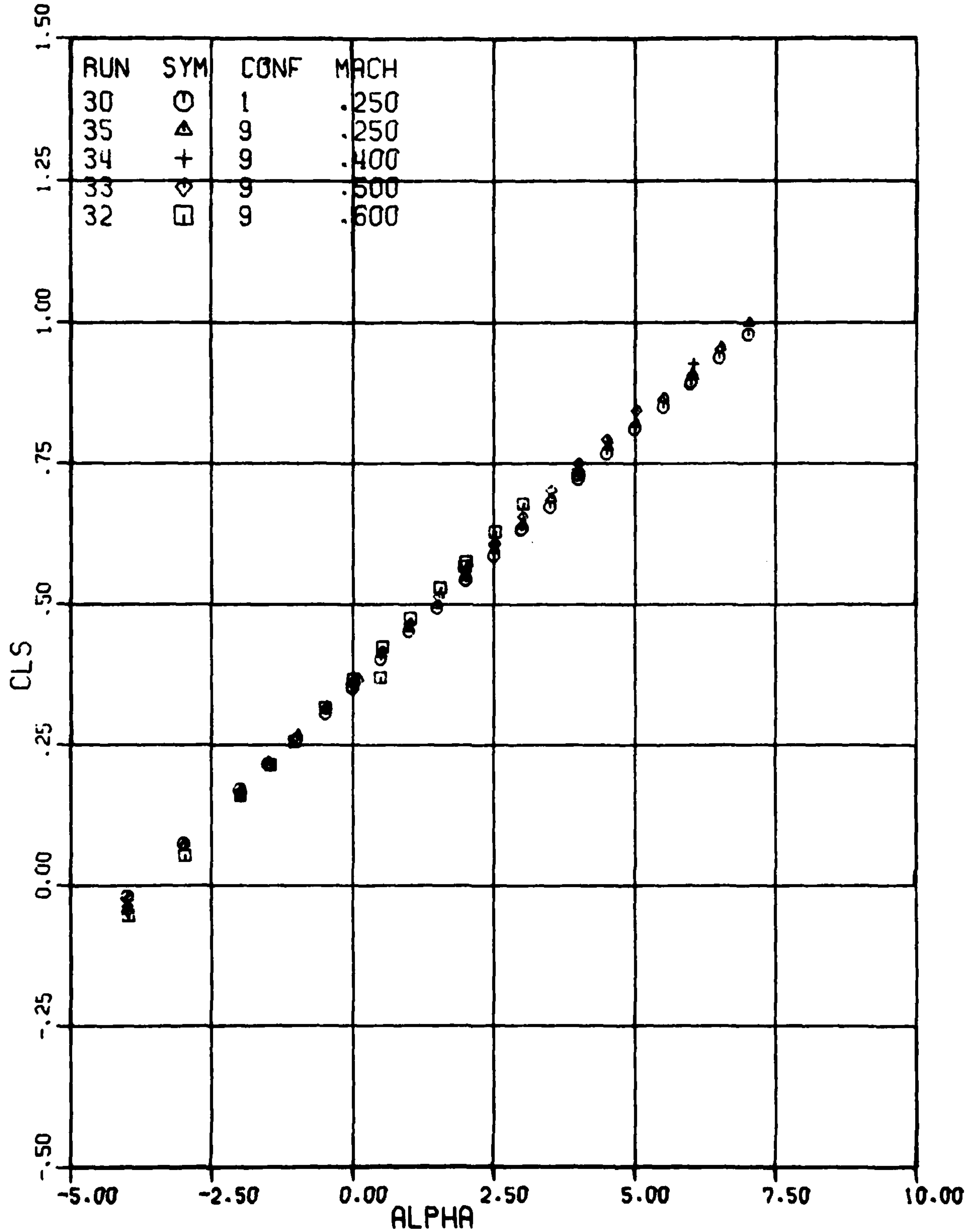
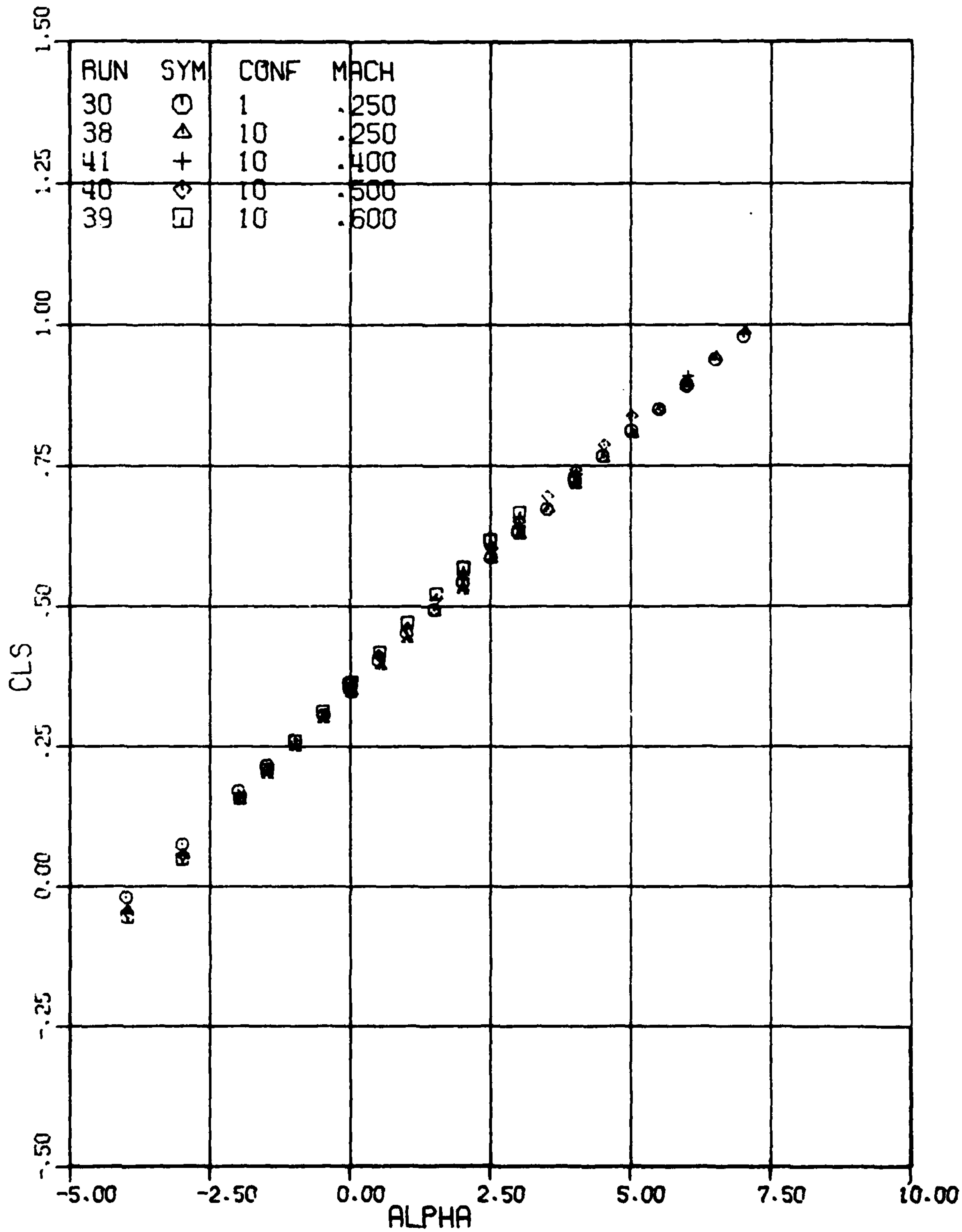
0.00
-.25
-.50
-5.00
-2.50
0.00
2.50
5.00
7.50
10.00

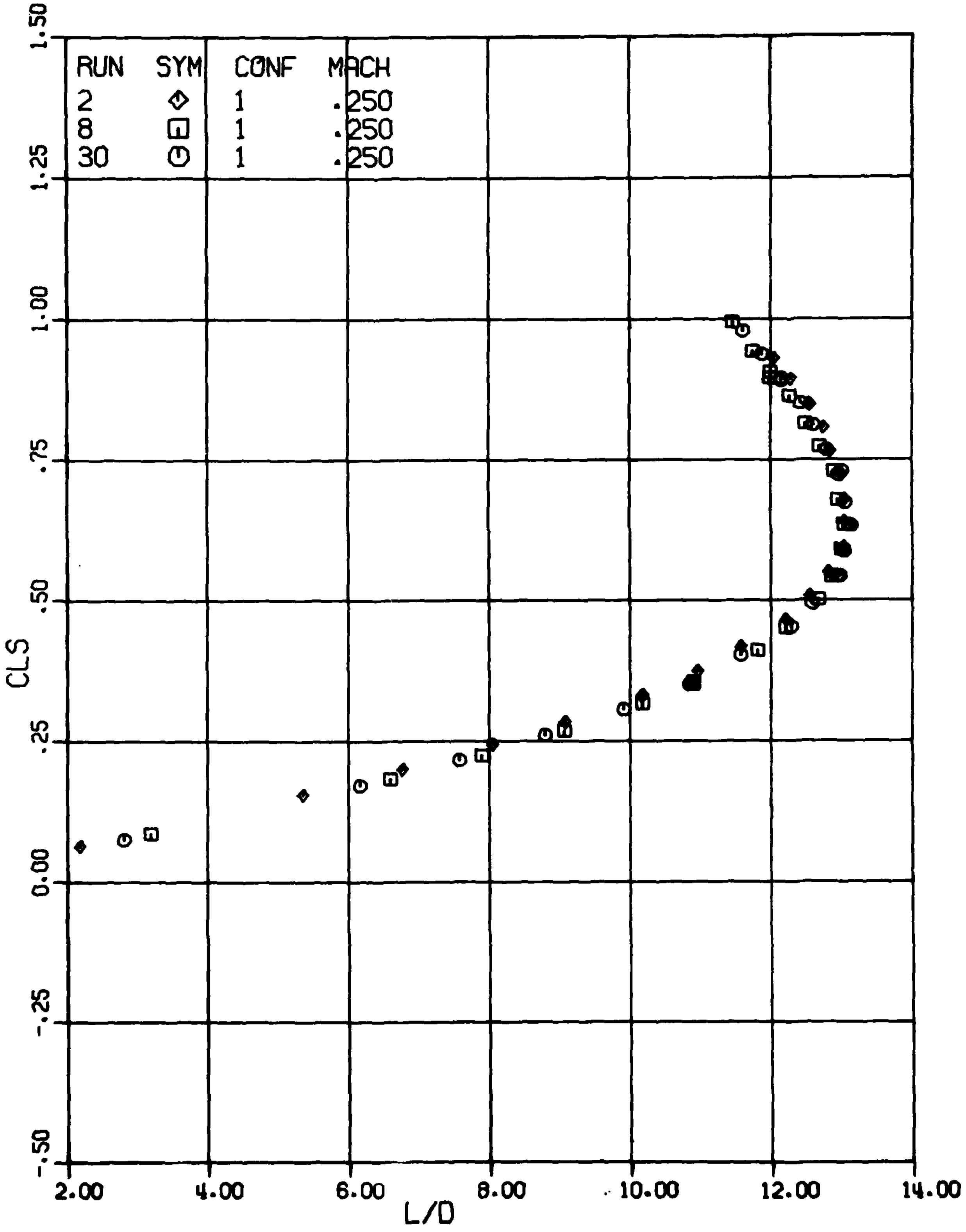

RUN SYM CONF MACH
8 1 .250
7 1 .400
6 1 .500
5 1 .600
4 1 .700
CLS
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
ALPHA
-5.00
-2.50
0.00
2.50
5.00
7.50
10.00


RUN SYM CONF MACH
30 1 .250
35 9 .250
34 9 .400
33 9 .500
32 9 .600
CLS
ALPHA
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
-5.00
-2.50
0.00
2.50
5.00
7.50
10.00


RUN SYM CONF MACH
30 1 .250
38 10 .250
41 10 .400
40 10 .500
39 10 .600
CLS
ALPHA
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
-5.00
-2.50
0.00
2.50
5.00
7.50
10.00

SECTION 3

LIFT COEFFICIENT VERSUS LIFT TO DRAG RATIO



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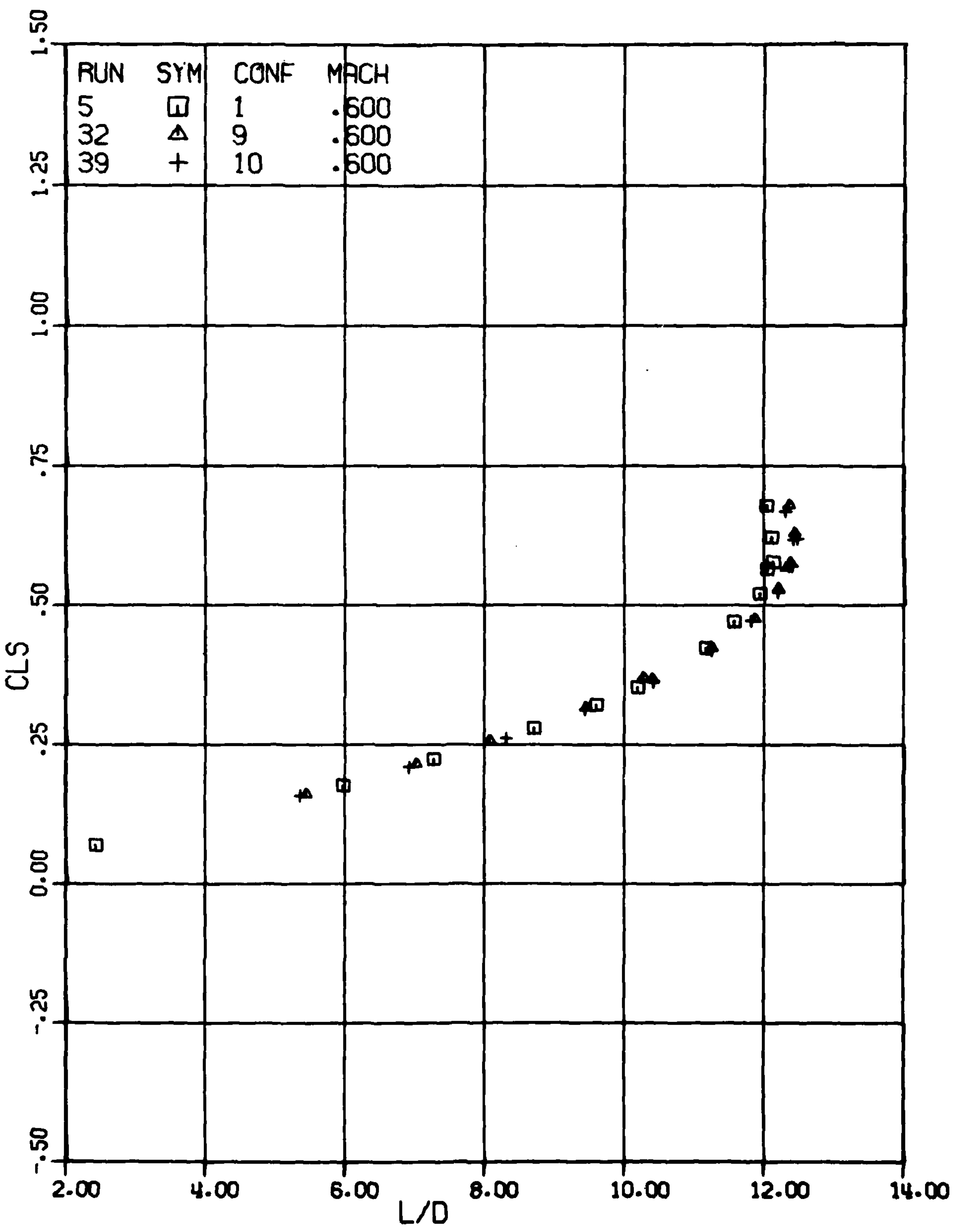
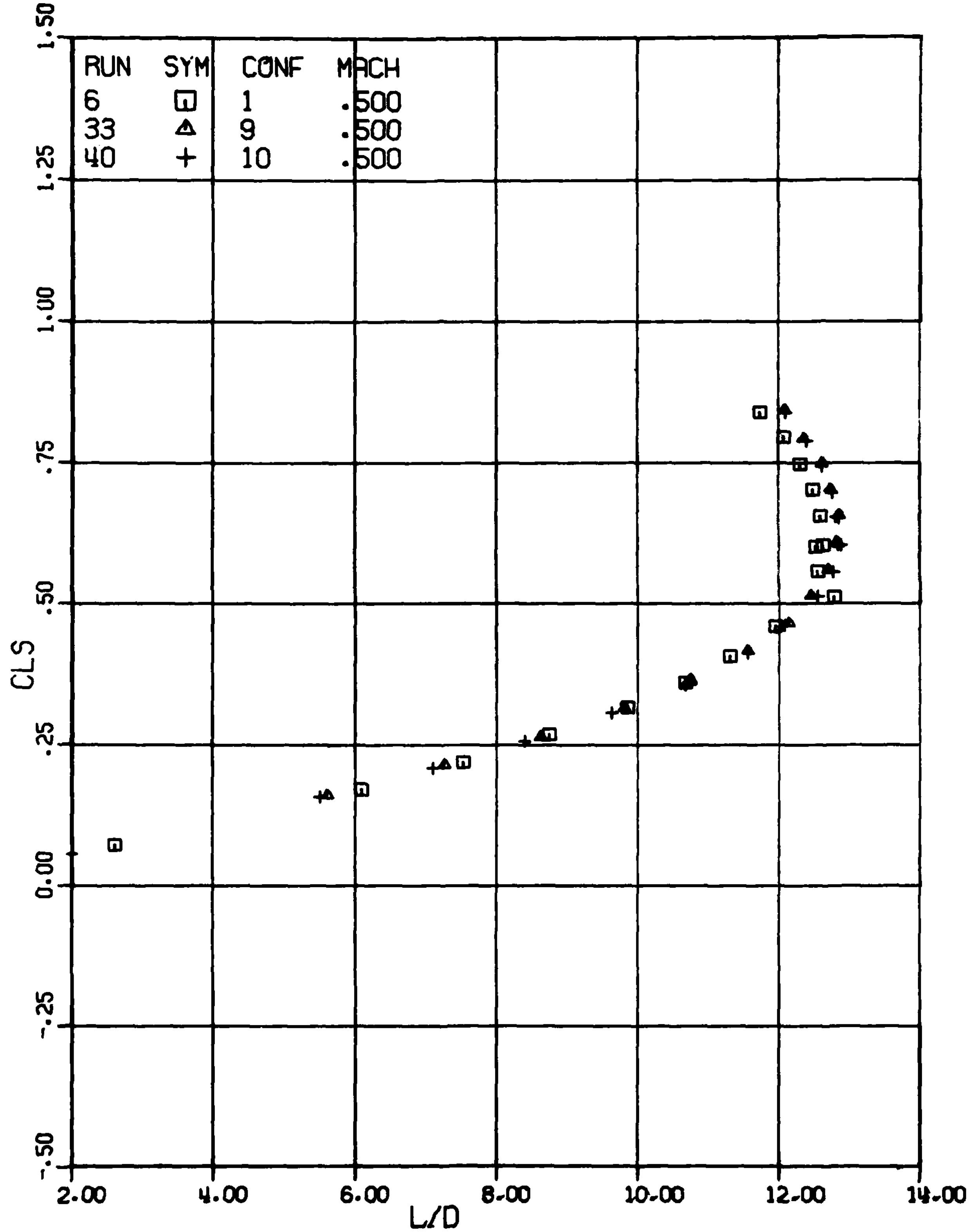
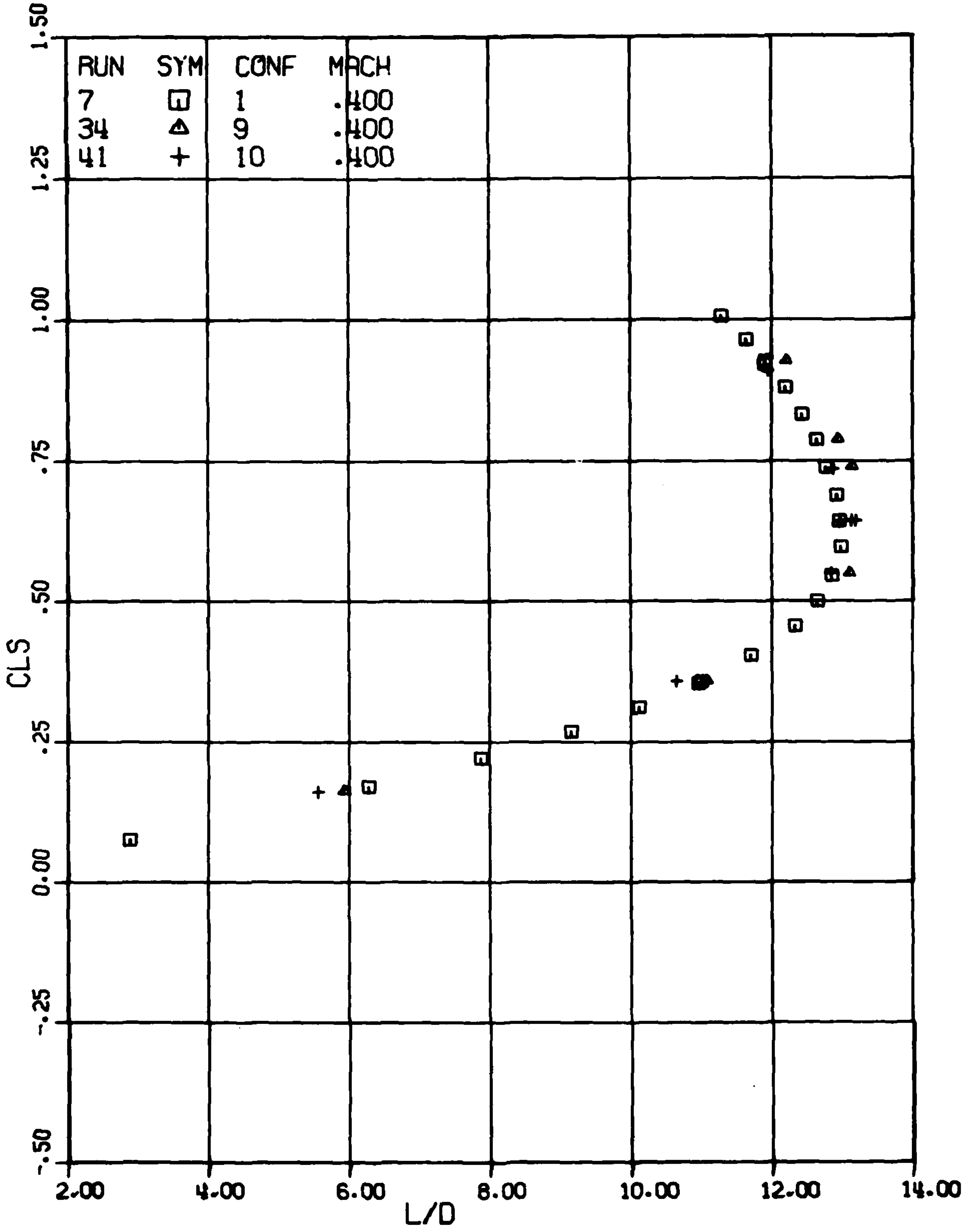
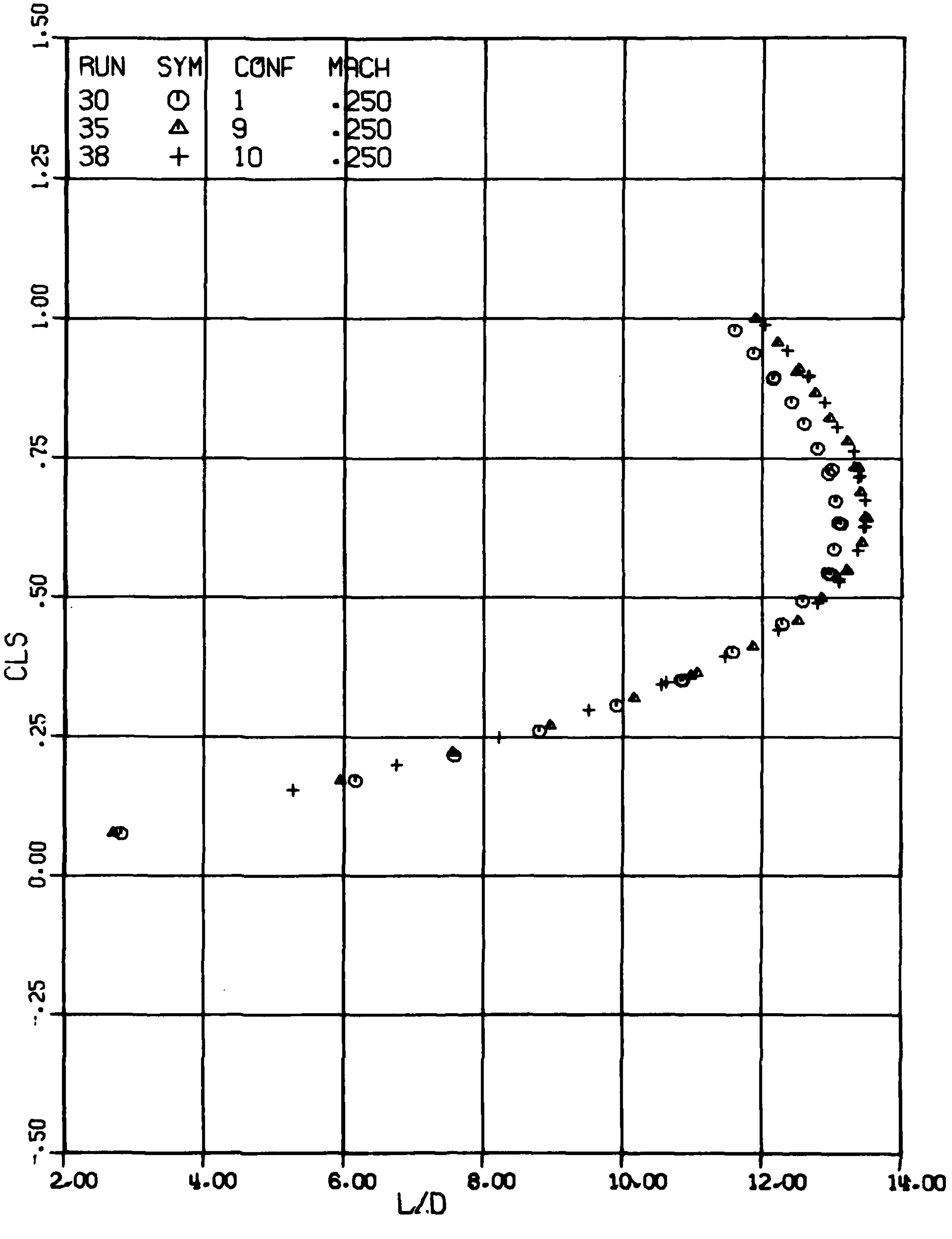
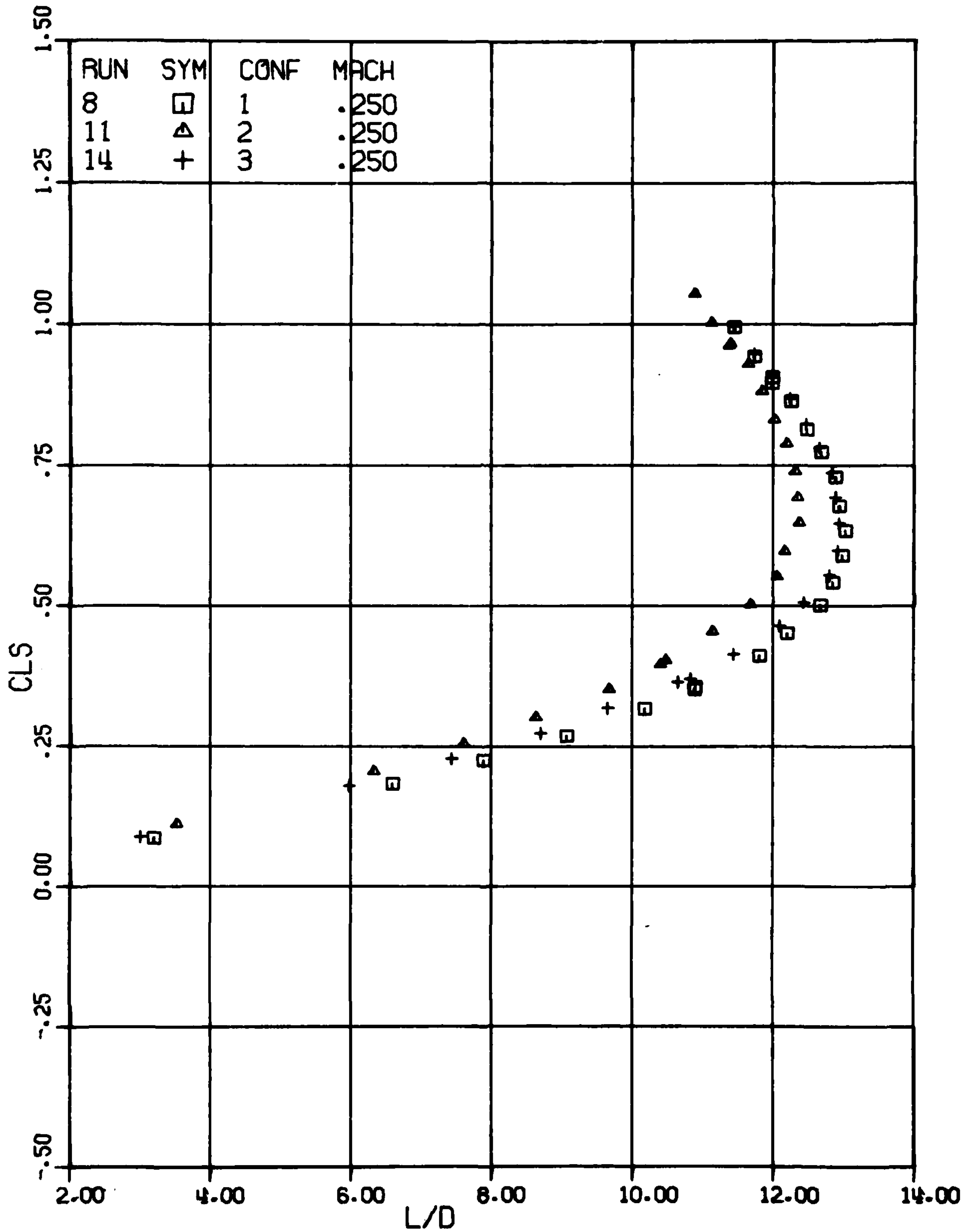
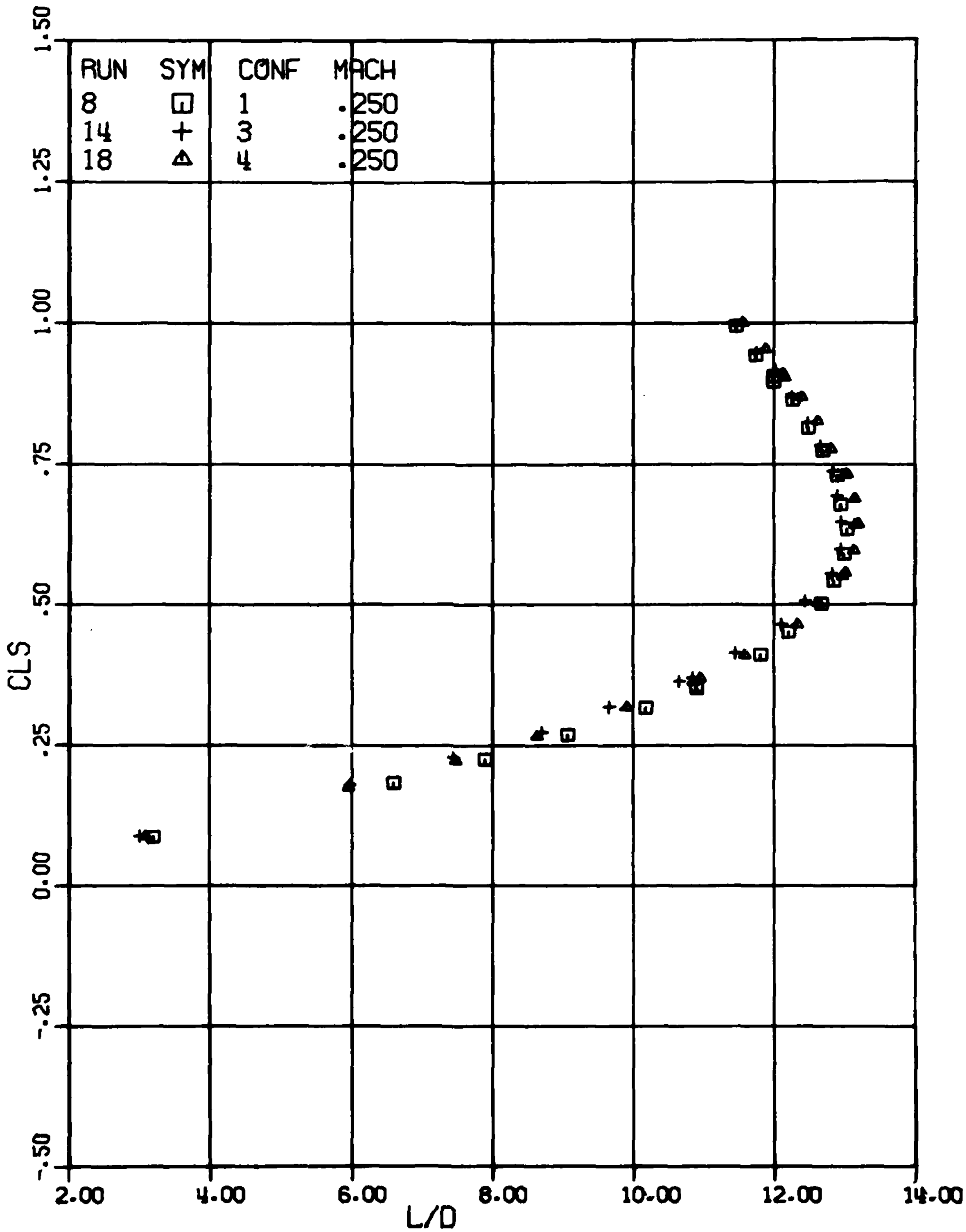

RUN SYM CONF MACH
5 1 .600
32 9 .600
39 10 .600
CLS
L/D
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
2.00
4.00
6.00
8.00
10.00
12.00
14.00

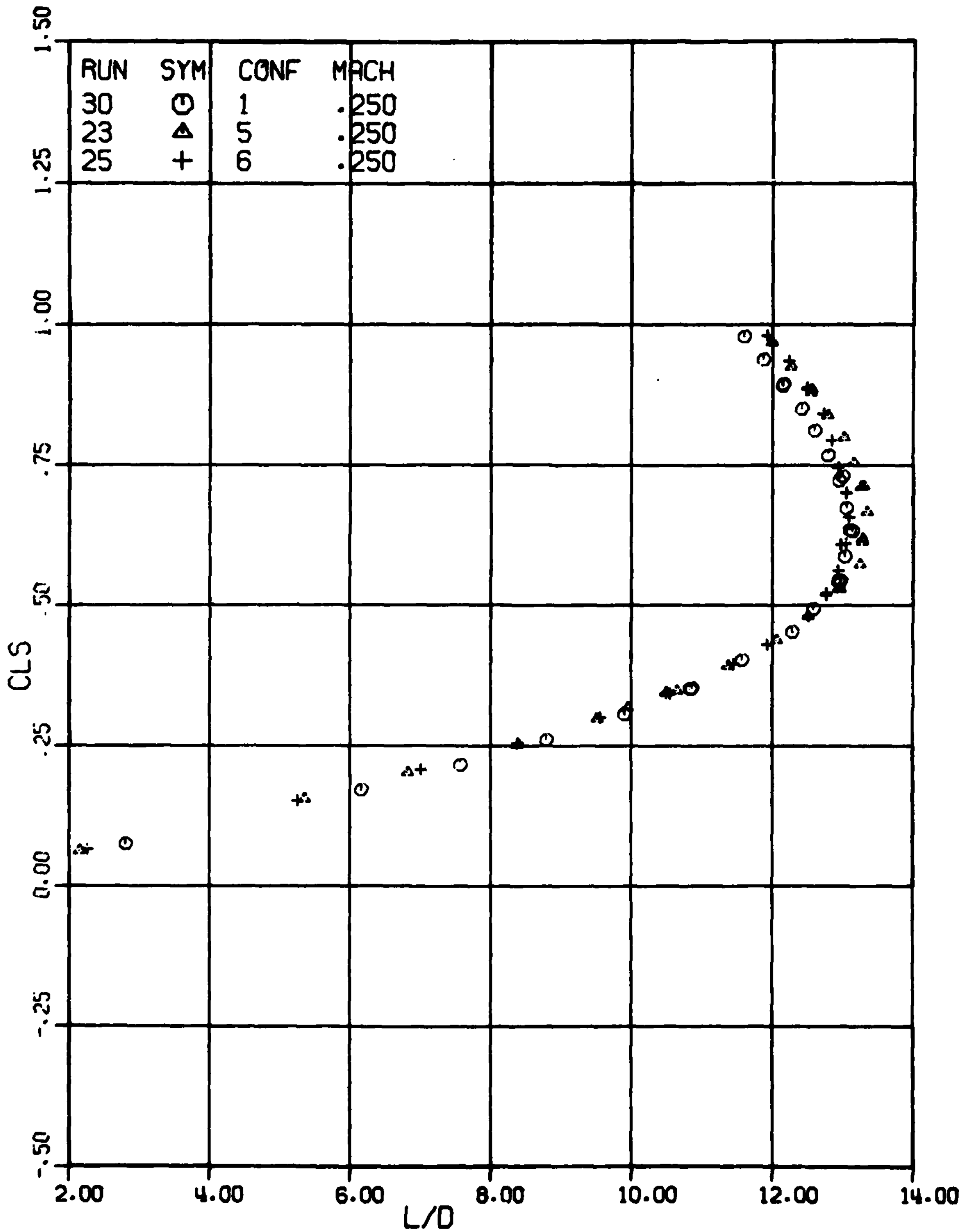

RUN SYM CONF MACH
6 □ 1 .500
33 △ 9 .500
40 + 10 .500
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
CLS
2.00
4.00
6.00
8.00
10.00
12.00
14.00
L/D

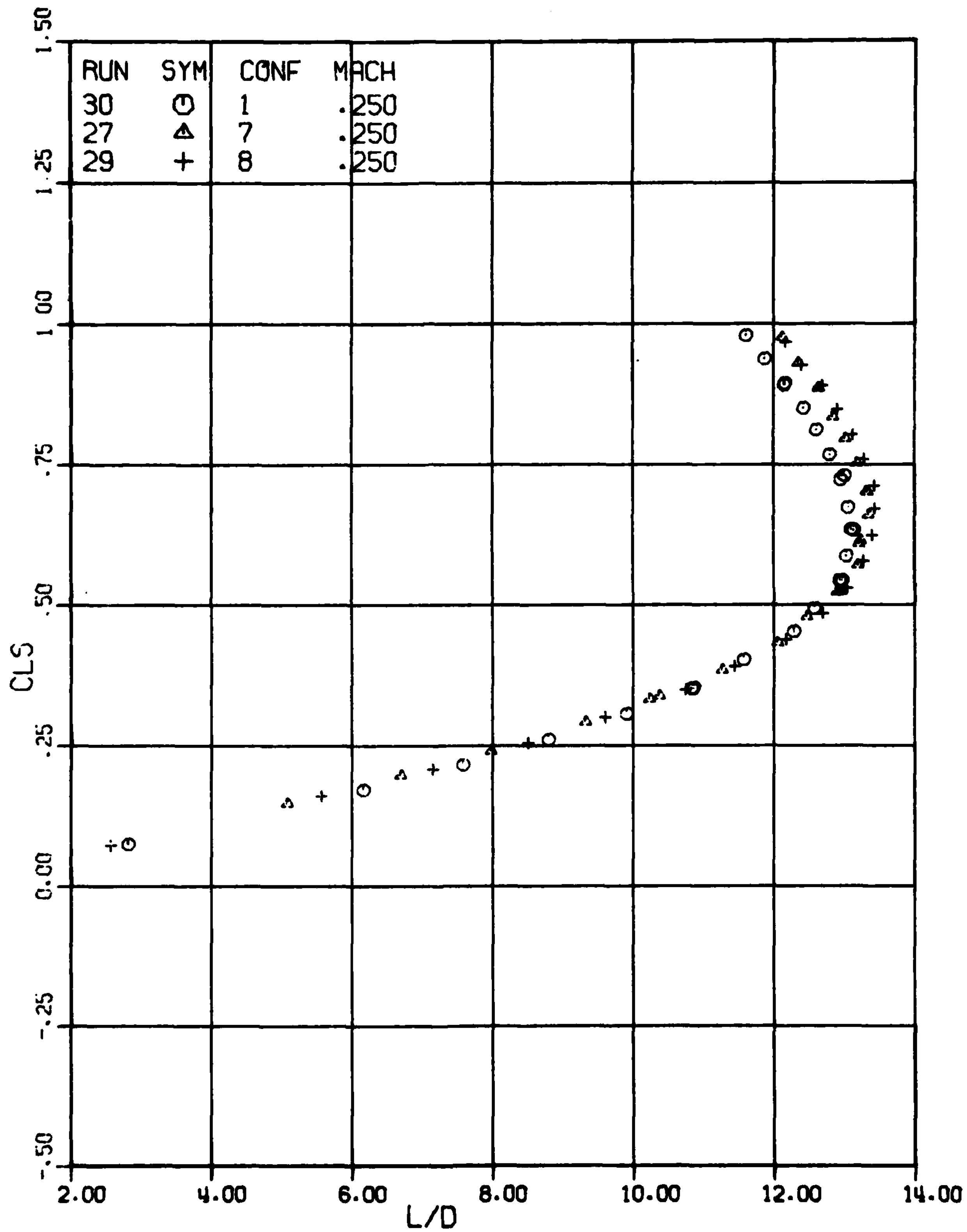

RUN SYM CONF MACH
7 □ 1 .400
34 △ 9 .400
41 + 10 .400
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
CLS
2.00
4.00
6.00
8.00
10.00
12.00
14.00
L/D

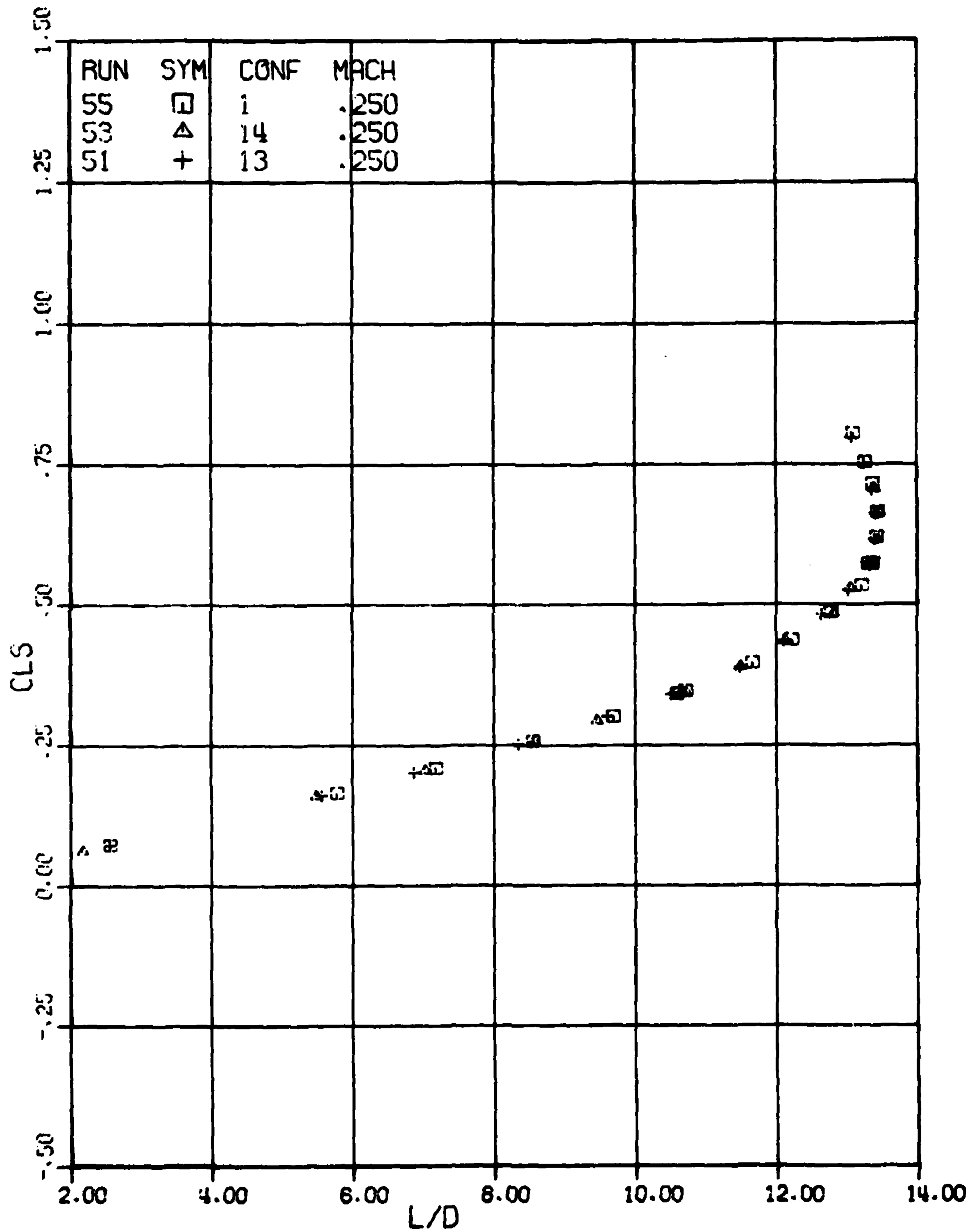

RUN SYM CONF MACH
30 1 .250
35 9 .250
38 + 10 .250
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
CLS
2.00
4.00
6.00
8.00
10.00
12.00
14.00
L/D

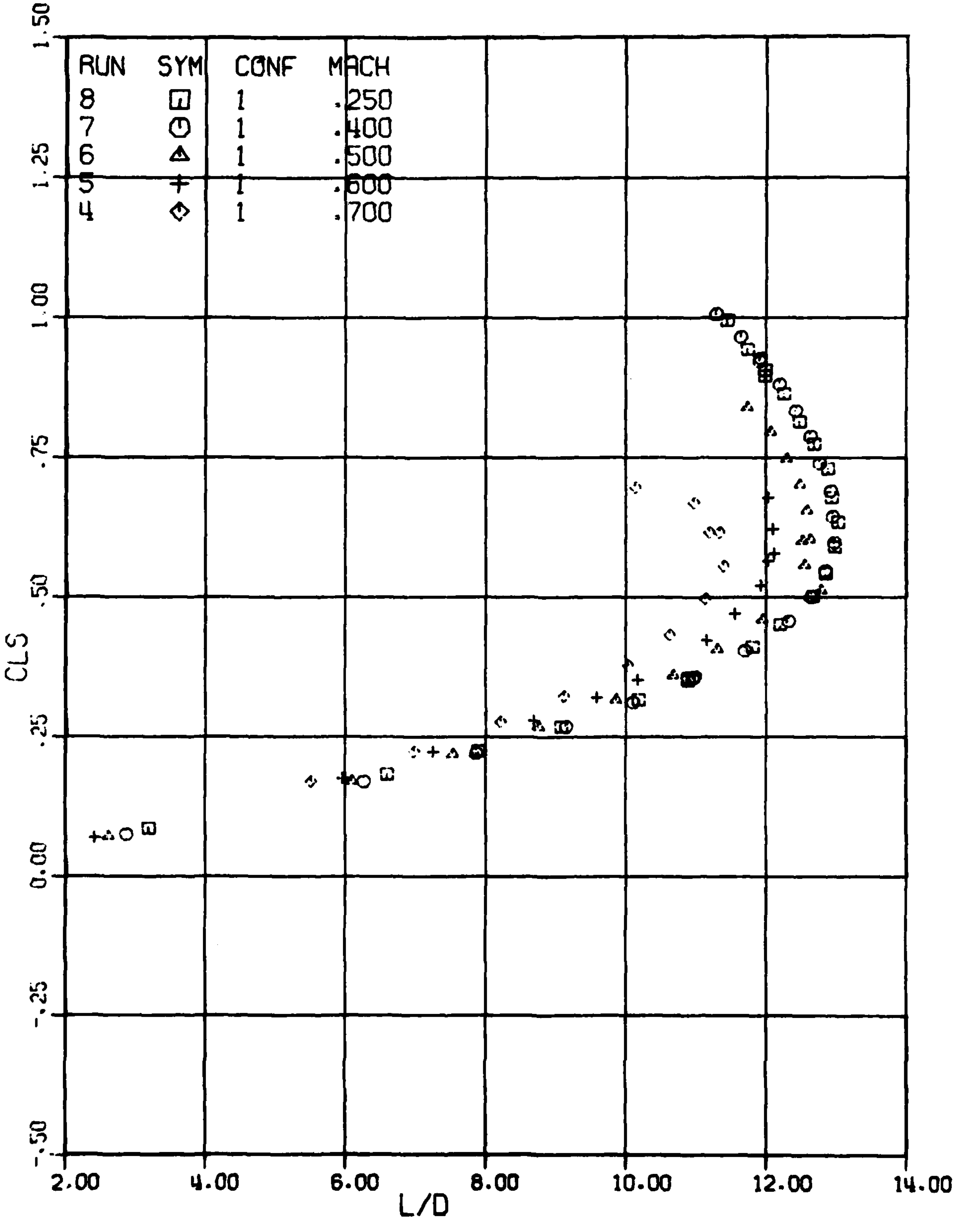

RUN SYM CONF MACH
8 ⊡ 1 .250
11 △ 2 .250
14 + 3 .250
CLS
L/D
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
2.00
4.00
6.00
8.00
10.00
12.00
14.00

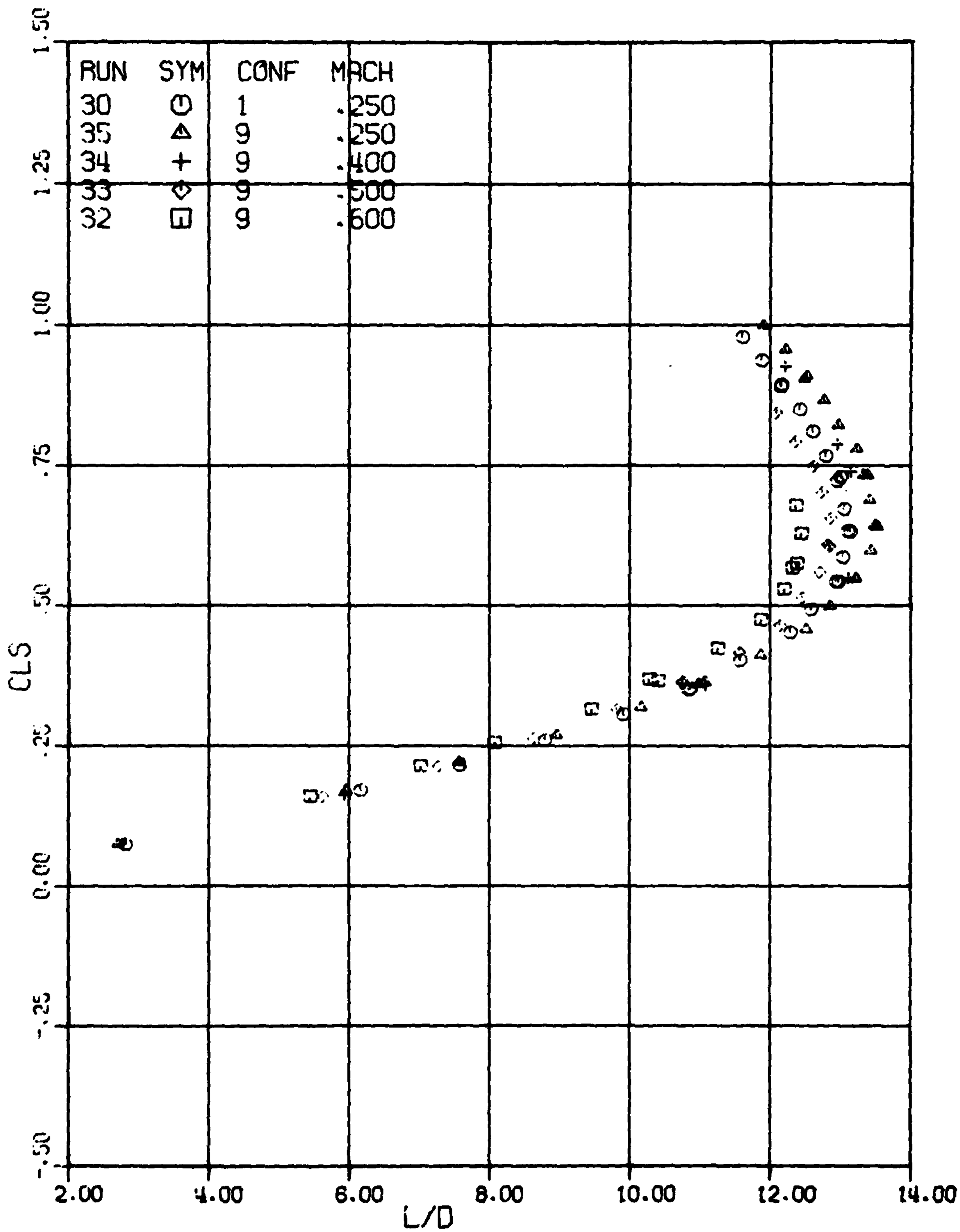

RUN SYM CONF MACH
8 ⊡ 1 .250
14 + 3 .250
18 △ 4 .250
CLS
L/D
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
2.00
4.00
6.00
8.00
10.00
12.00
14.00

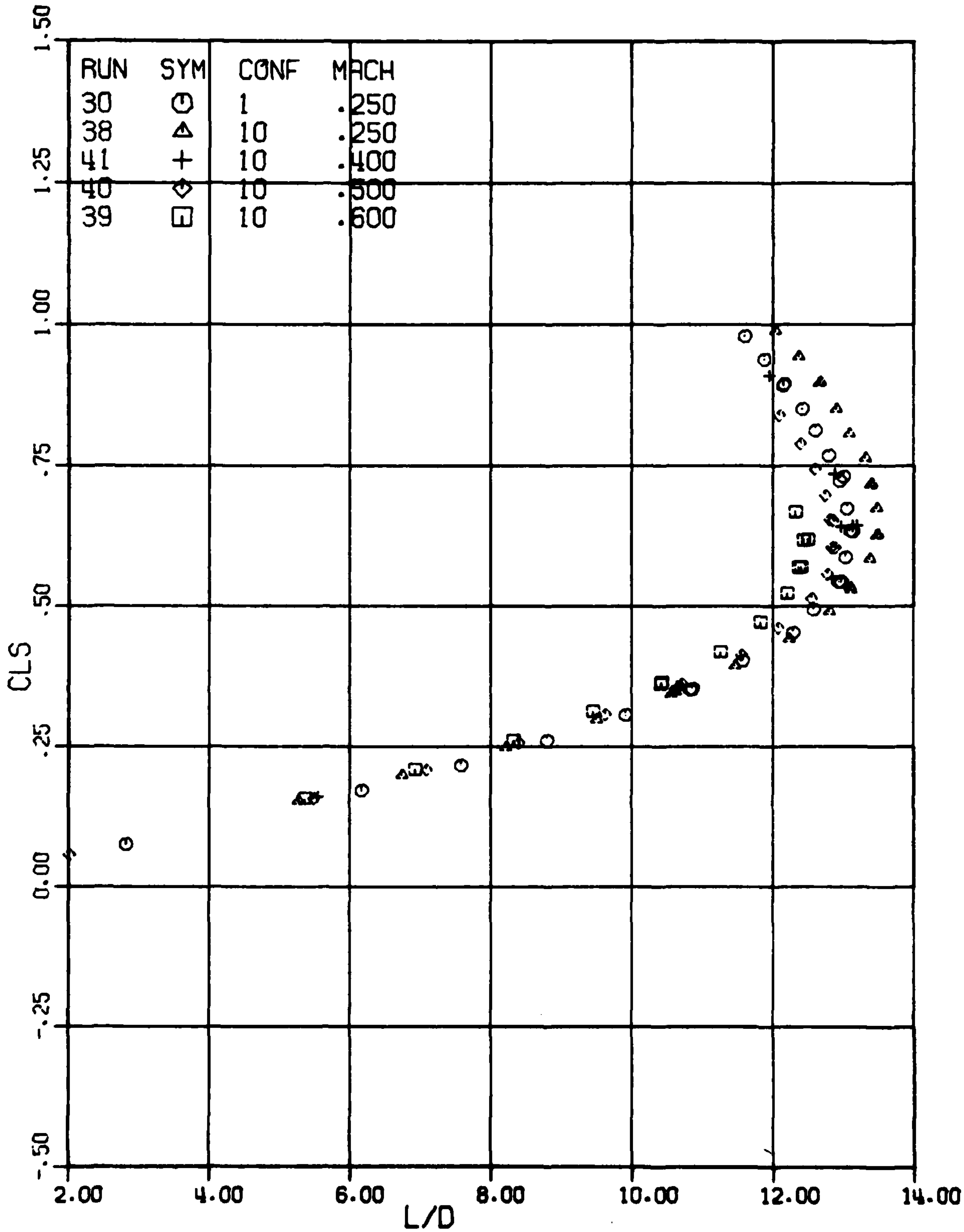

RUN SYM CONF MACH
30 O 1 .250
23 Δ 5 .250
25 + 6 .250
CLS
L/D
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
2.00
4.00
6.00
8.00
10.00
12.00
14.00


RUN SYM CONF MACH
30 ⊙ 1 .250
27 △ 7 .250
29 + 8 .250
CLS
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
2.00
4.00
6.00
8.00
10.00
12.00
14.00
L/D


RUN SYM CONF MACH
55 □ 1 .250
53 △ 14 .250
51 + 13 .250
CLS
L/D
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
2.00
4.00
6.00
8.00
10.00
12.00
14.00

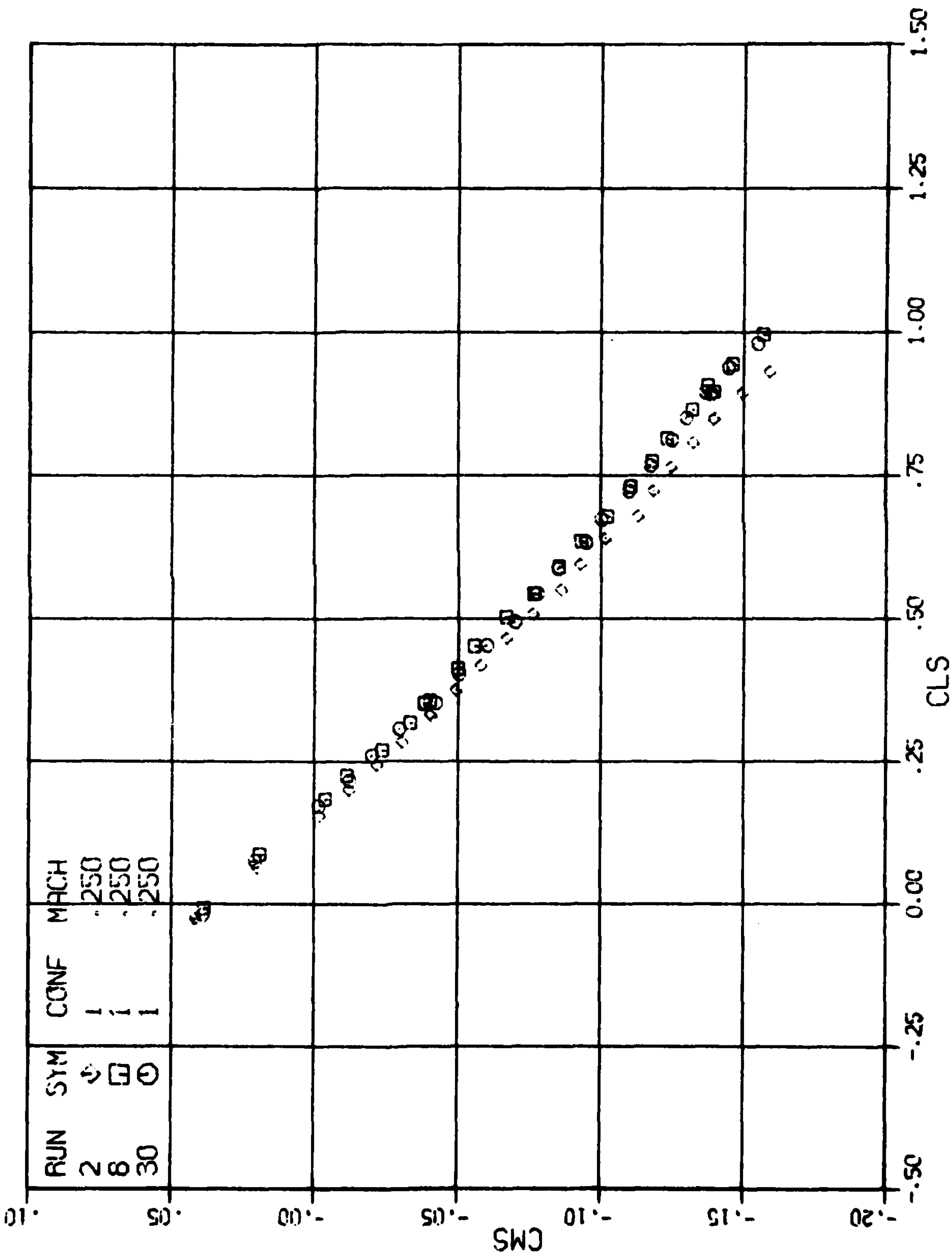

RUN SYM CONF MACH
8 1 .250
7 1 .400
6 1 .500
5 1 .600
4 1 .700
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
CLS
2.00
4.00
6.00
8.00
10.00
12.00
14.00
L/D


RUN SYM CONF MACH
30 1 .250
35 9 .250
34 9 .400
33 9 .500
32 9 .600
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
CLS
2.00
4.00
6.00
8.00
10.00
12.00
14.00
L/D


RUN SYM CONF MACH
30 1 .250
38 10 .250
41 10 .400
40 10 .500
39 10 .600
CLS
L/D
1.50
1.25
1.00
.75
.50
.25
0.00
-.25
-.50
2.00
4.00
6.00
8.00
10.00
12.00
14.00

SECTION 4

PITCHING MOMENT COEFFICIENT VERSUS LIFT COEFFICIENT



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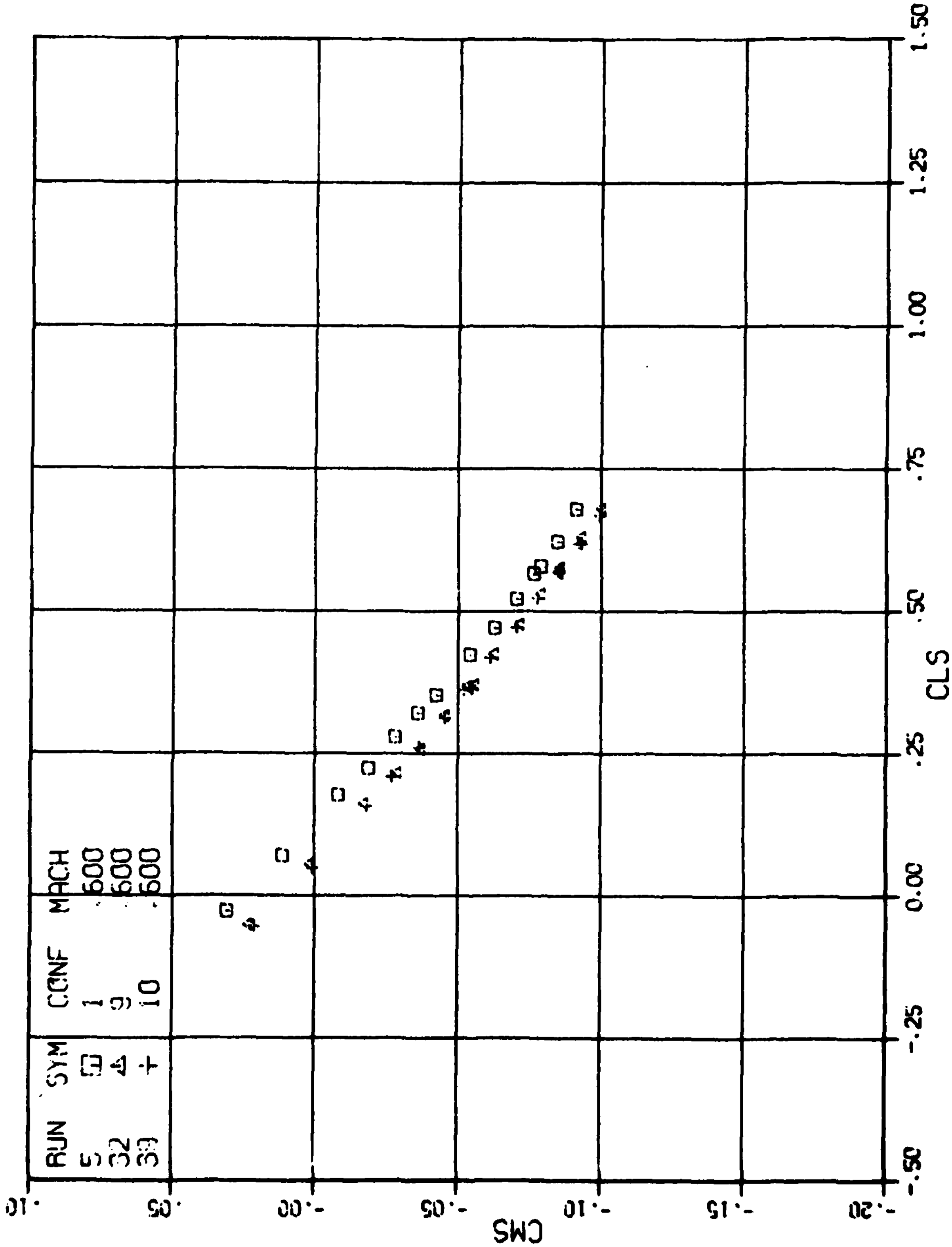
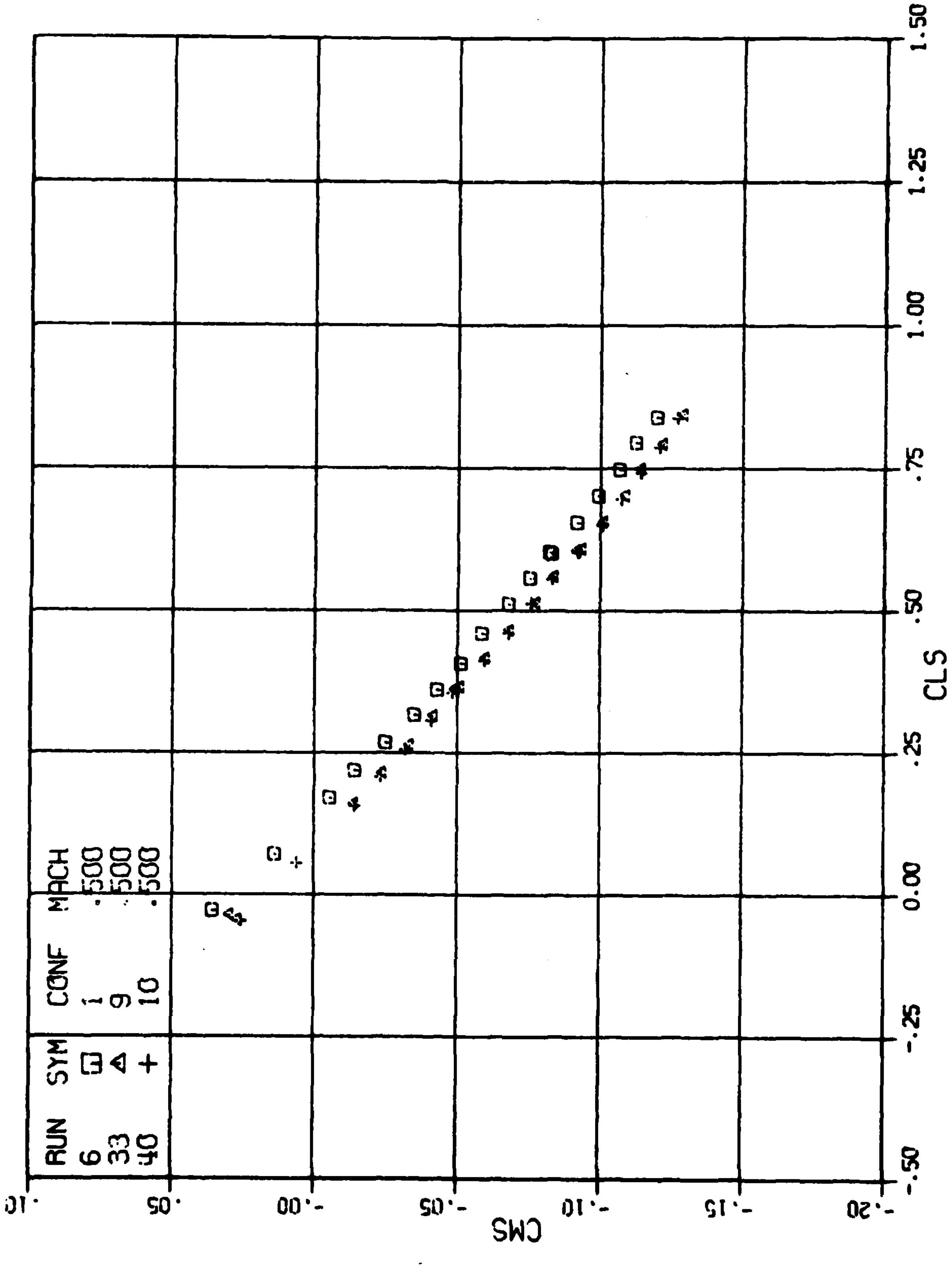
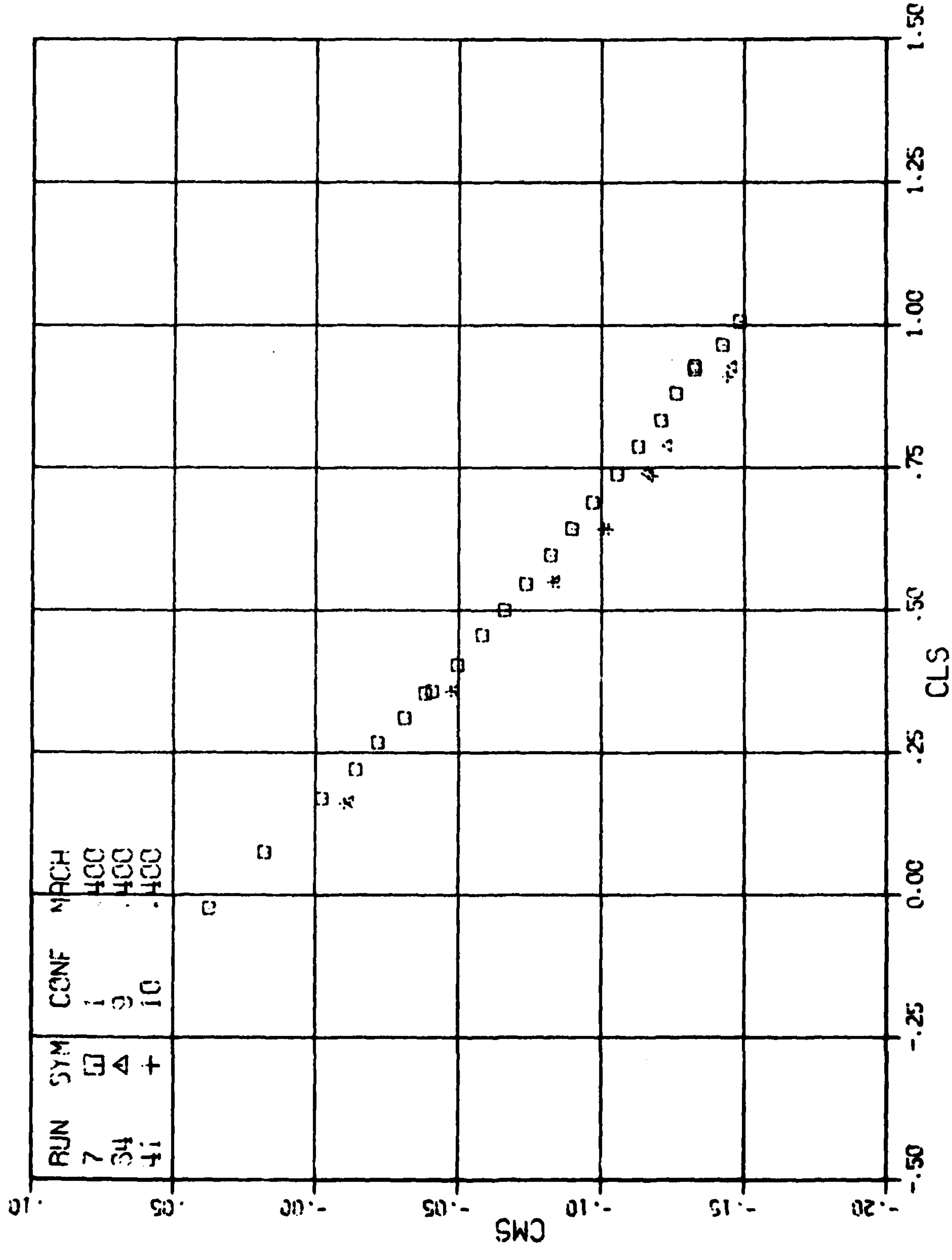
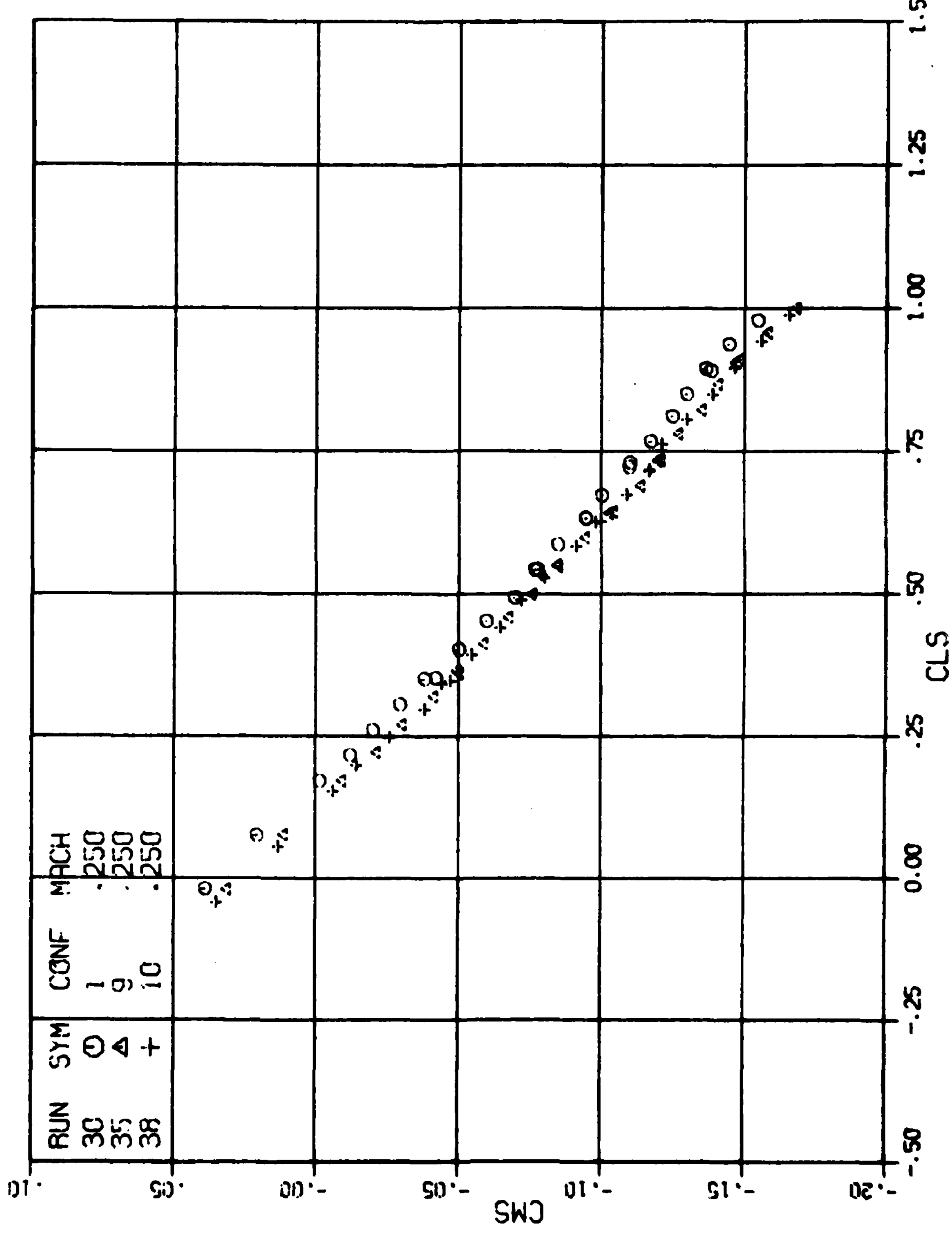
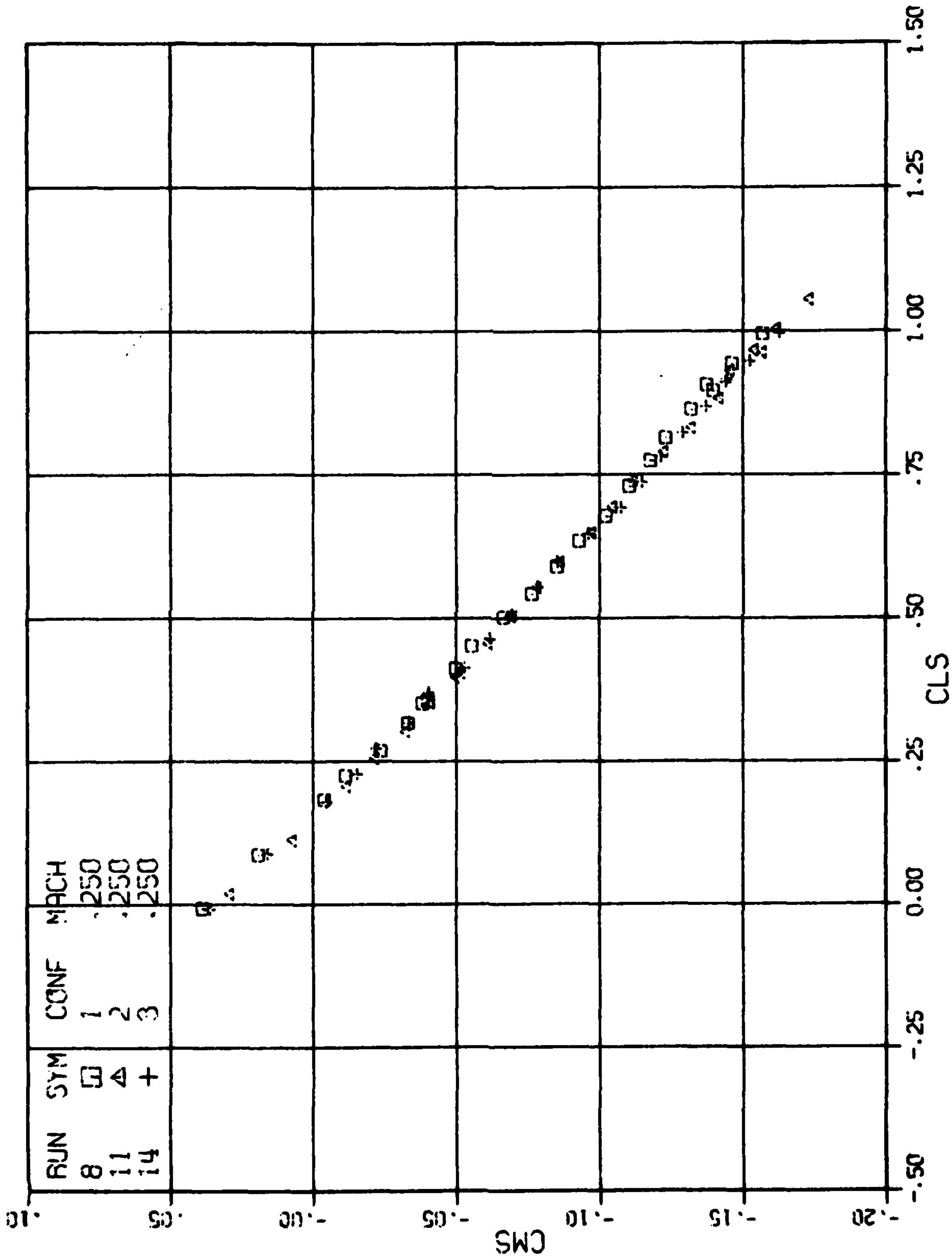

RUN SYM CONF MACH
5 ⊡ 1 .600
32 △ 9 .600
39 + 10 .600
CLS
-.50 -.25 0.00 .25 .50 .75 1.00 1.25 1.50
CMS
.10 .05 -.00 -.05 -.10 -.15 -.20

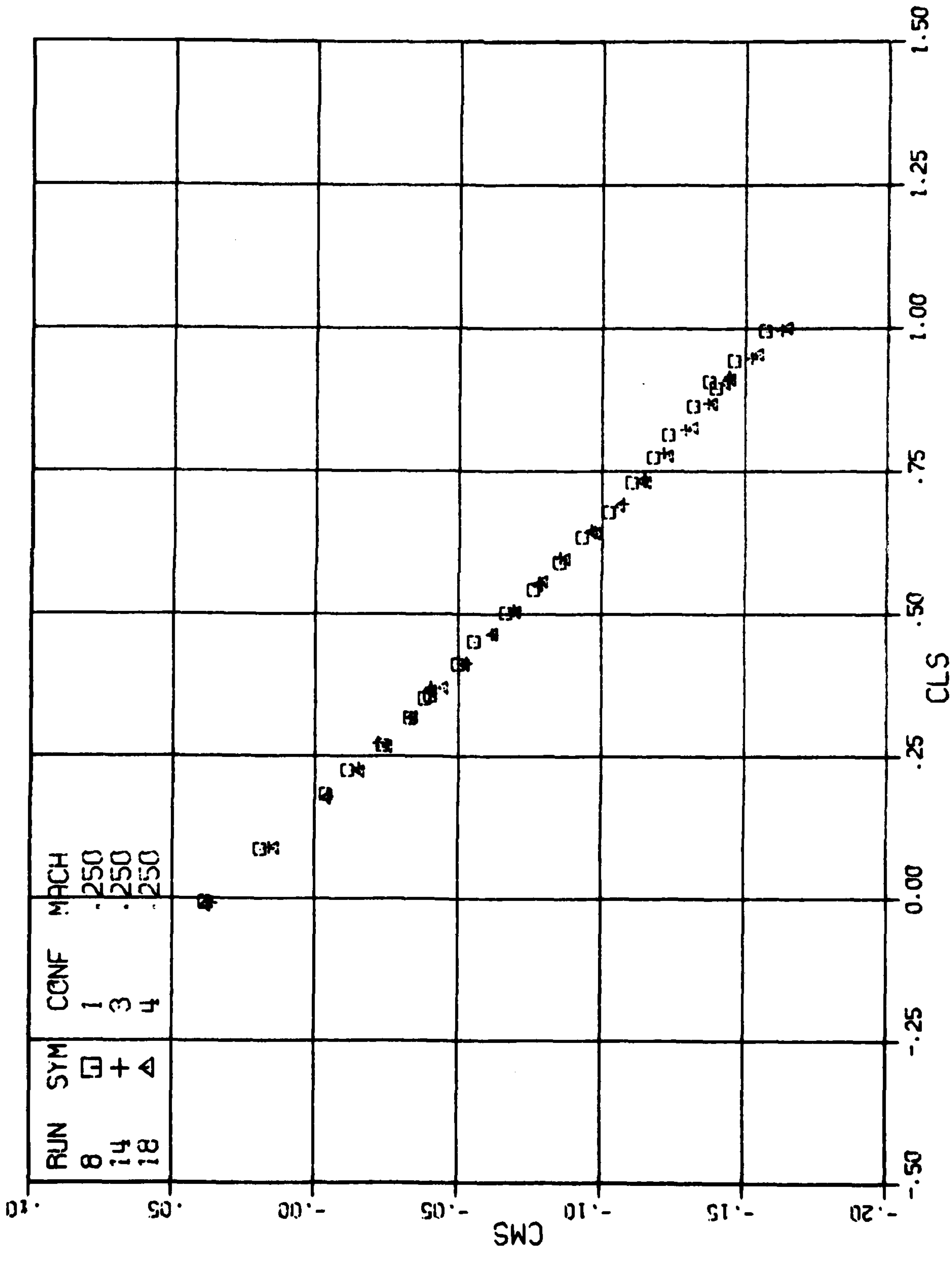


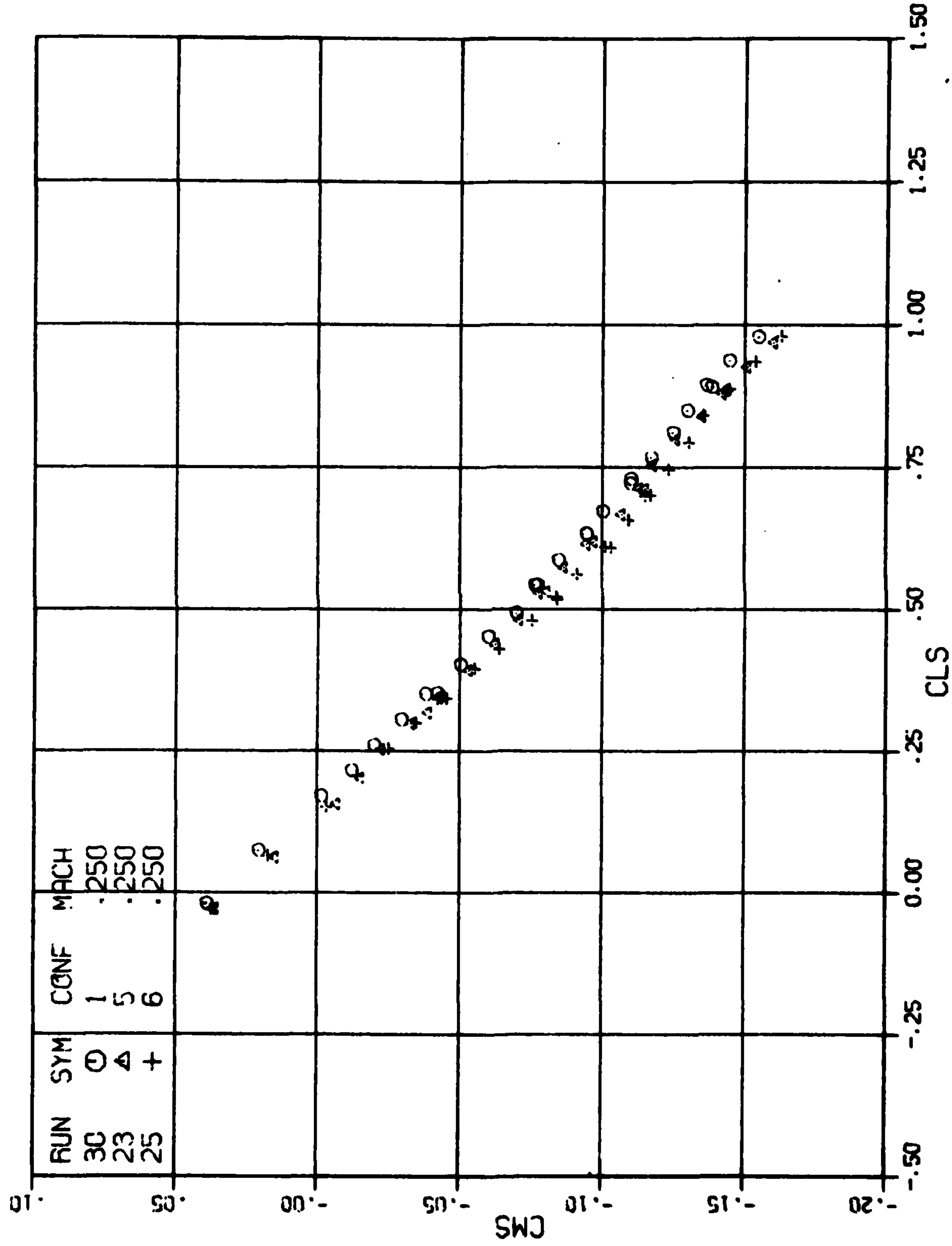
RUN SYM CONF MACH
6 □ 1 .500
33 △ 9 .500
40 + 10 .500
CLS
CMS
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50
.10
.05
-.00
-.05
-.10
-.15
-.20


RUN SYM CONF MACH
7 □ 1 .400
34 △ 9 .400
41 + 10 .400
CLS
CMS
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50
.10
.05
-.00
-.05
-.10
-.15
-.20


RUN SYM CONF MACH
30 ⊙ 1 .250
35 △ 9 .250
38 + 10 .250
CLS
CMS
-.50 -.25 0.00 .25 .50 .75 1.00 1.25 1.50
.10 .05 -.00 -.05 -.10 -.15 -.20


RUN SYM CONF MACH
8 □ 1 .250
11 △ 2 .250
14 + 3 .250
CLS
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50
CMS
.10
.05
-.00
-.05
-.10
-.15
-.20


RUN SYM CONF MACH
8 □ 1 .250
14 + 3 .250
18 △ 4 .250
CLS
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50
CMS
.10
.05
-.00
-.05
-.10
-.15
-.20


RUN SYM CONF MACH
30 ⊙ 1 .250
23 △ 5 .250
25 + 6 .250
-.50
-.25
0.00
.25
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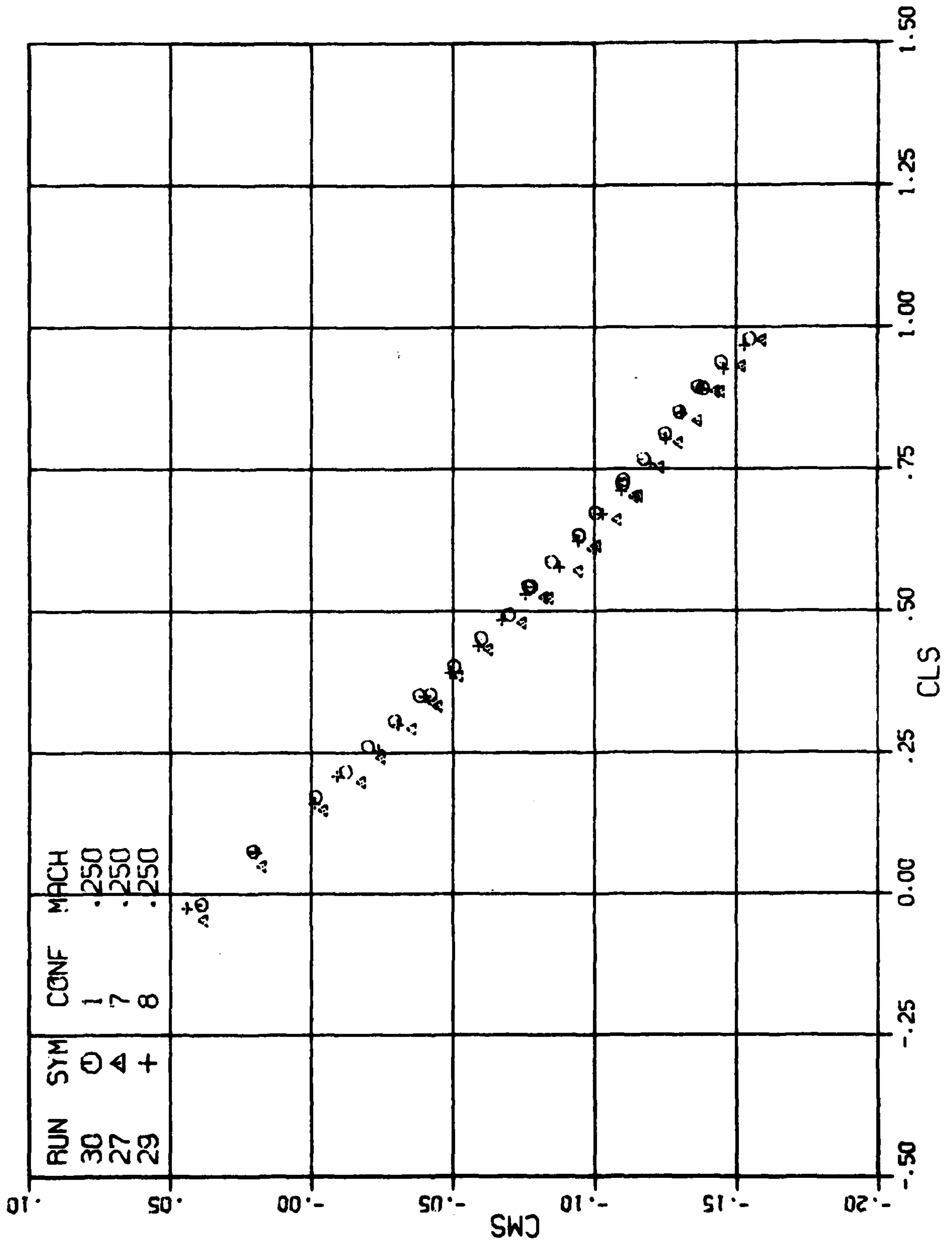
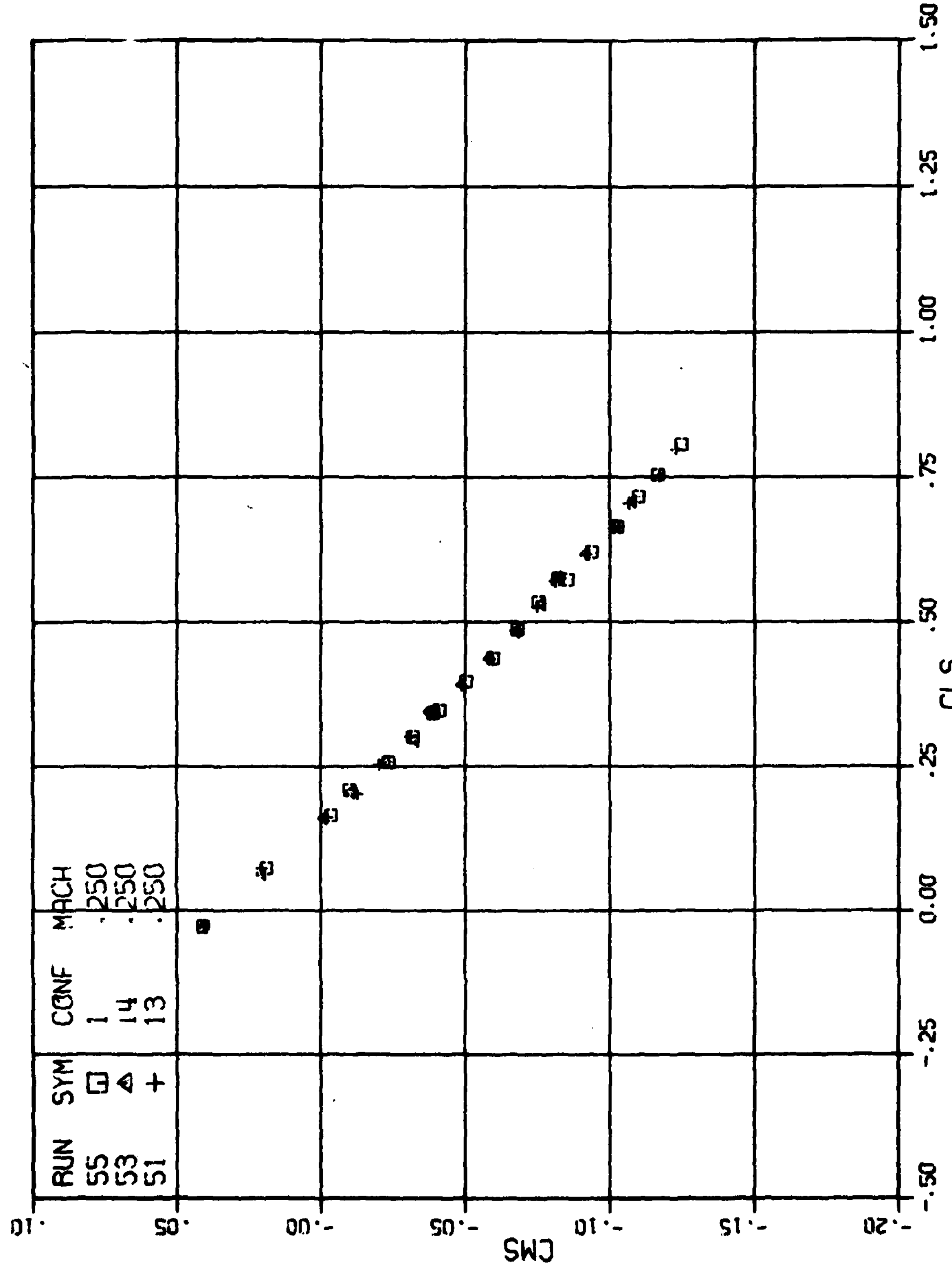
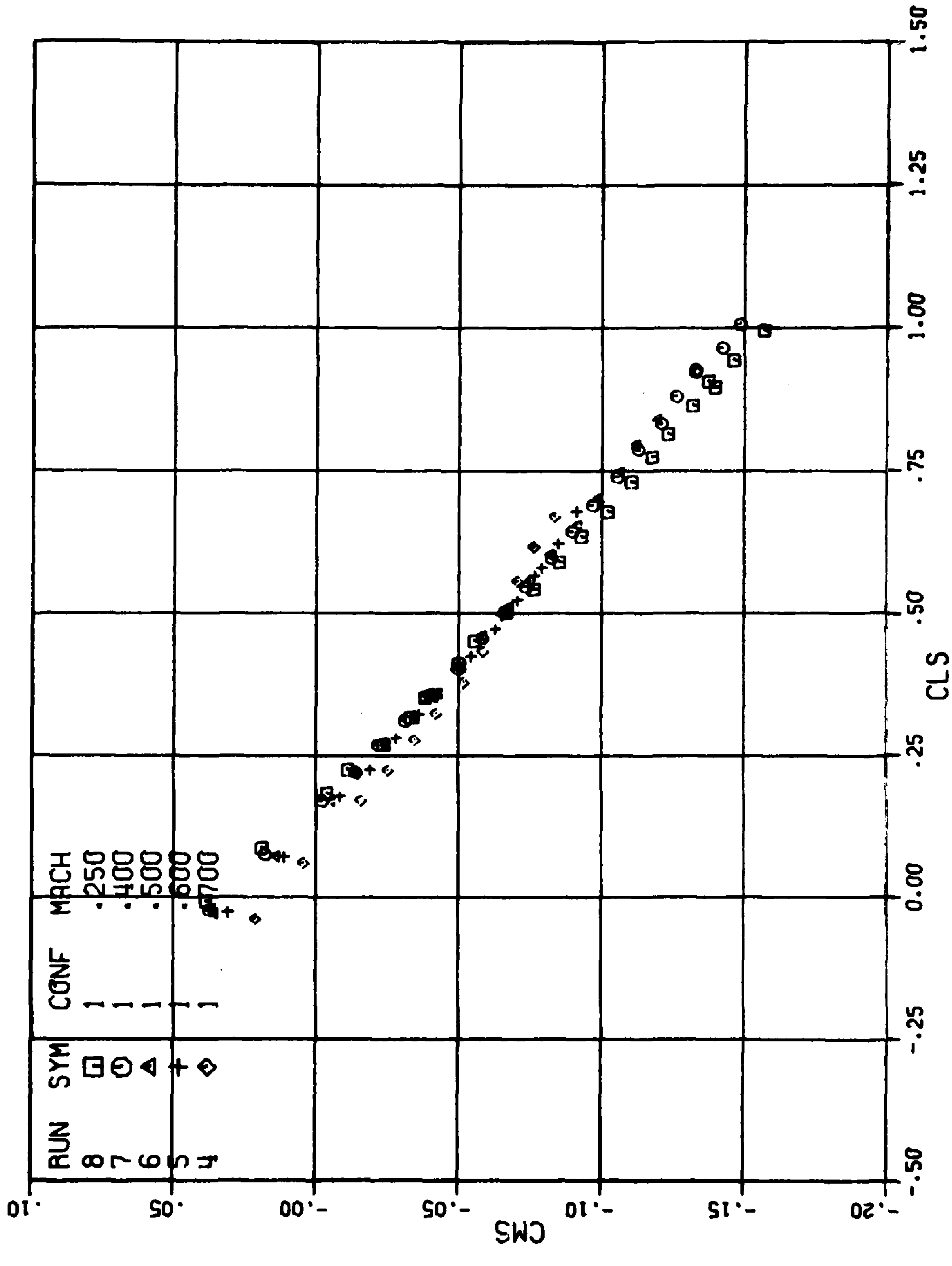
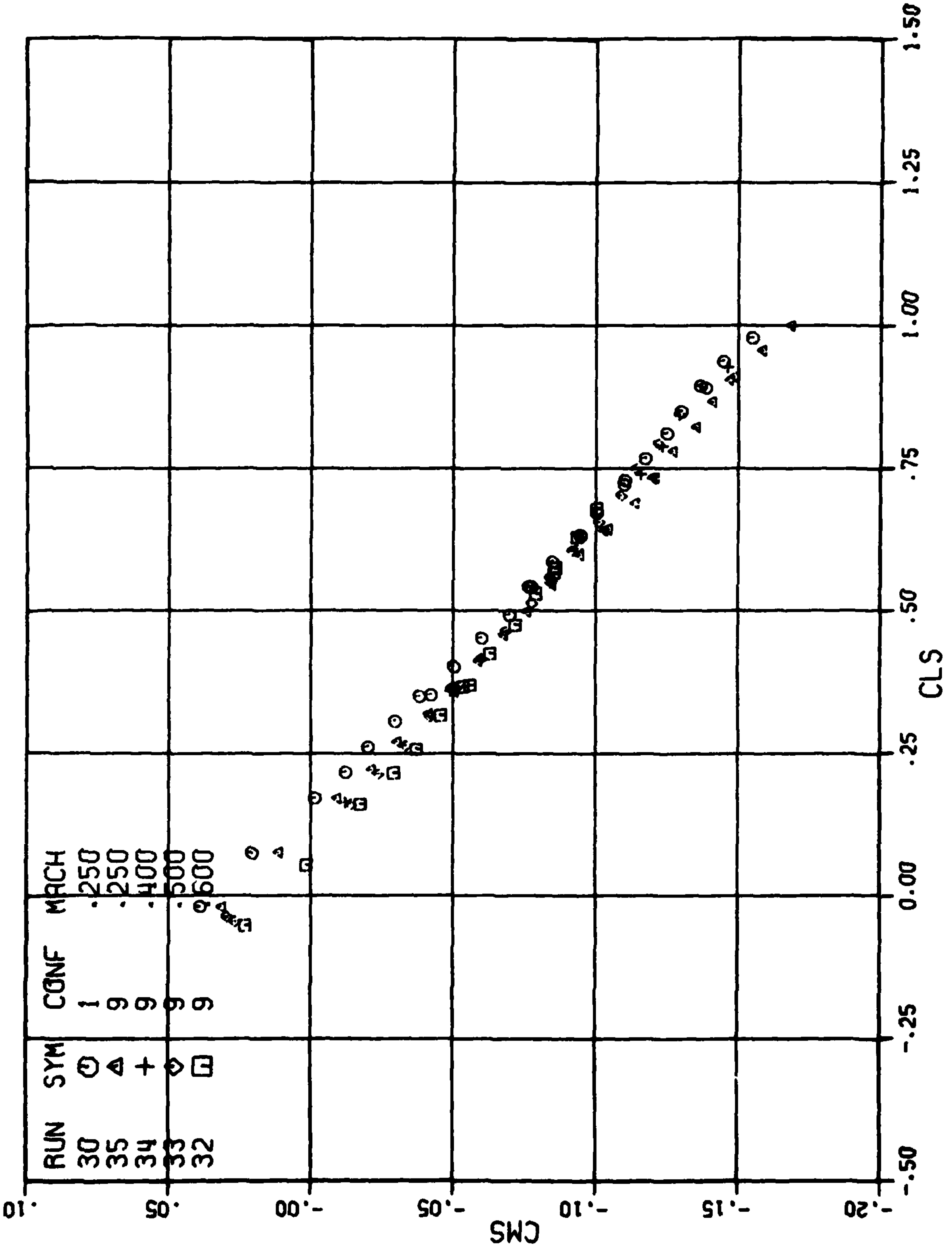
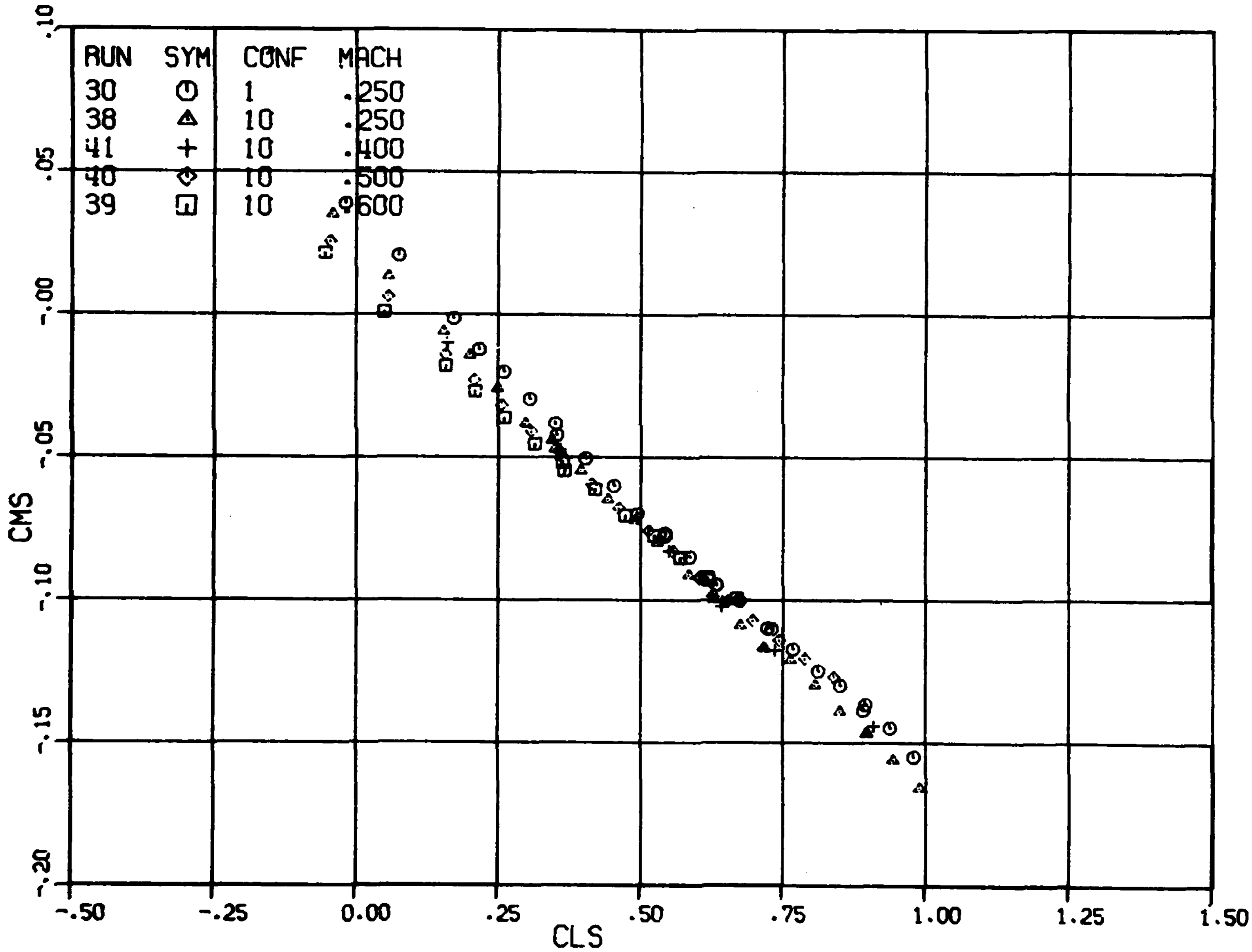
.75
1.00
1.25
1.50
CLS
.10
.05
-.00
-.05
-.10
-.15
-.20
CMS


RUN SYM CONF MACH
30 ⊙ 1 .250
27 △ 7 .250
29 + 8 .250
CLS
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50
CMS
.10
.05
-.00
-.05
-.10
-.15
-.20


RUN SYM CONF MACH
55 □ 1 .250
53 △ 14 .250
51 + 13 .250
CMS
.10
.05
-.00
-.05
-.10
-.15
-.20
CLS
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50


RUN SYM CONF MACH
8 1 .250
7 1 .400
6 1 .500
5 1 .600
4 1 .700
CLS
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50
CMS
.10
.05
-.00
-.05
-.10
-.15
-.20


RUN SYM CONF MACH
30 1 .250
35 9 .250
34 9 .400
33 9 .500
32 9 .600
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50
CLS
.10
.05
-.00
-.05
-.10
-.15
-.20
CMS



RUN SYM CONF MACH
30 ⊙ 1 .250
38 △ 10 .250
41 + 10 .400
40 ◇ 10 .500
39 ⊡ 10 .600
.10
.05
-.00
-.05
-.10
-.15
-.20
CMS
-.50
-.25
0.00
.25
.50
.75
1.00
1.25
1.50
CLS